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PAPERS IN PRESS FOR FORTHCOMING ISSUES

PETROGENESIS OF BALD ROCK BATHOLITH, CALIFORNIA: A NEW PETROGRAPHIC STUDY. By Leonard H Larsen and Arie Poldervaart

RADIOCARBON DATING OF LATE QUATERNARY DEPOSITS, SOUTH LOUISIANA. By E. McFarlan, Jr.

PALEOGEOGRAPHIC EVOLUTION OF THE LAKE SUPERIOR REGION FROM LATE KEWEENAWAN TO LATE CAMBRIAN TIME. By William Kenneth Hamblin

PETROLOGY OF THREE VOLCANIC SUITES, UNMAK AND BOGOSLOF ISLANDS, ALEUTIAN ISLANDS, ALASKA. By Frank M. Byers, Jr.

SAN ANDREAS FAULT NORTH OF SAN FRANCISCO, CALIFORNIA. By C. G. Higgins

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DEGRADATIONAL STREAM DEPOSITS OF THE BRAZOS RIVER, CENTRAL TEXAS. By Fred L. Stricklin, Jr.

Editor's Note: Separate copies of *Correlation of the Permian formations of North America* (Chart 7), printed in this issue, are available at 50 cents per copy.

Separate copies of *Correlation of Cretaceous formations of the Pacific Coast* (Chart 10e), printed in the October issue, are available at 50 cents per copy.

NEW FOREIGN BIBLIOGRAPHY

BIBLIOGRAPHY AND INDEX OF GEOLOGY EXCLUSIVE OF NORTH AMERICA. Volume 23. By Marie Siegrist, Mary C. Grier, and others

Price, $13.00

Special price to Fellows and Members of GSA, $8.50

MEMOIR IN PRESS

83. BIOSTRATIGRAPHIC STUDIES IN THE COMANCHE (CRETACEOUS) SERIES OF NORTHERN MEXICO AND TEXAS. By Bob F. Perkins

About 135 p., 26 figures, 34 plates

Expected date of issue, January

NEW MEMOIRS

81. MORPHOLOGY, CLASSIFICATION, AND LIFE HABITS OF THE PRODUCTOIDEA (BRACHIOPODA). By Helen Muir-Wood and G. Arthur Cooper

Comprehensive revision of the Productoidea. Includes all genera in the world literature, plus new families and genera, and their stratigraphic ranges and distribution. New information and interpretations of shell structure and other features. The authors propose a new classification for Productoidea. Extensive bibliography and illustrations of almost all genera.

448 pages, 8 figures, 135 photographic collotype plates

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82. OLIGOCENE PLANTS FROM THE UPPER RUBY BASIN, SOUTHWESTERN MONTANA. By Herman F. Becker

Description of a well-preserved flora (37 families, 61 genera, and 82 identifiable species, 25 of which are new) from Tertiary fossiliferous shales of the Ruby Basin. The author uses the flora to interpret the paleoecology and paleoclimatology and suggests that the Ruby and Florissant assemblages represent a single botanical province.

About 120 pages, 4 figures, 32 photographic plates

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ABSTRACTS OF PAPERS SUBMITTED FOR THE MEETING IN DENVER, OCTOBER 31–NOVEMBER 2, 1960

BIOGEOCHEMISTRY OF THE STABLE ISOTOPES OF CARBON

Philip H. Abelson and Thomas C. Hoering
Geophysical Laboratory, Carnegie Institution of Washington, Washington, D. C.

When inorganic carbon is converted into living matter, the light isotope of carbon tends to be preferentially fixed. This effect was first noticed by Nier, and extensive studies of recent and ancient organic matter have been conducted by a number of workers, including Craig, Epstein, and Wickman.

Many fundamental questions can be asked. Is this isotope fractionation characteristic of photosynthetic organisms in general? Are there any significant differences in isotope abundances among specific compounds, and, if such differences exist, can they be related to known biochemical processes?

Research in this laboratory has begun to answer these questions. The isotopic composition of the carbon in amino acids isolated from cultures of a number of different photosynthetic micro-organisms has been investigated. Major effort has been devoted to the green alga, *Chlorella pyranoidosa*, which can be grown on a completely inorganic medium with the sole source of carbon being the carbon dioxide fed to the system.

Typical results relative to tank CO_2 are: Total organic carbon, $\delta = -18.9$; aspartic acid, $\delta = -6.6$; carboxyl carbons of aspartic acid, $\delta = +2.2$; leucine, $\delta = -22.7$; alanine, $\delta = -10.3$; serine, $\delta = -5.7$; arginine, $\delta = -19.2$; carboxyl of arginine, $\delta = -2.6$. With more detailed knowledge it may become possible to use C^{13}/C^{12} ratios to identify and follow changes in organic carbon after deposition.

THORIUM AND URANIUM CONTENT OF THE ENCHANTED ROCK BATHOLITH, TEXAS

John A. S. Adams, Mary-Cornelia Kline, and John J. W. Rogers
Rice University, Houston, Texas

The Enchanted Rock batholith is a peripherally zoned granitic intrusion in Llano and Gillespie counties, Texas; representative samples collected from the various zones of the batholith, from late intrusions within the batholith, and from metamorphic rocks at the contact were analyzed for thorium, uranium, and potassium by gamma-ray spectrometry.

High heterogeneous values of thorium and uranium occur both within the outer zone of the batholith and in the late intrusions. Local petrographic variations of the rocks are generally accompanied by variations in concentration of thorium and uranium. These local variations, however, are not consistent throughout the batholith. In the contact zone, a few rocks sampled indicate that thorium and uranium may have migrated with potassium into the surrounding metamorphic rocks.

The migration of thorium and uranium into the outer zone is believed to have been structurally controlled during the emplacement of the batholith. Marginal fissures and joints developed in the outer crystallized portion of the batholith while the inner core was still rising. The joint system thereby preferentially allowed the emplacement of the late intrusions within the outer zone and provided paths for the migration of thorium and uranium. The core of the batholith contains relatively few joints, and the concentrations of thorium and uranium are lower but more uniform there.

EFFECT OF GEOLOGICAL ENVIRONMENT ON SEISMIC COUPLING

William M. Adams and Lawrence M. Swift
3905 Stanford Way, Livermore, Calif.; Stanford Research Institute, Menlo Park, Calif.

Two experiments on the coupling of seismic waves to the surrounding medium have been conducted. One was performed at two different overburden depths in a tunnel complex at the Nevada Test Site

in the Oak Spring tuff; the other was done at a depth of 800 feet in the Carey Salt Mine at the Winnfield Salt Dome, near Winnfield, Louisiana. Free field measurements within 400 feet of the chemical charges indicate that 3–4 times more energy was propagated into the elastic zone in the tuff than in the salt. Qualitatively, this value was consistent with decoupling studies in the salt medium. In tuff the amount of energy transmitted into the elastic zone was found to be dependent on the lithostatic overburden pressure. Doubling the overburden quadrupled the energy propagated into the elastic zone. The values given in this abstract are subject to revision on further analysis of the data.

FLOOD-PLAIN SEDIMENTS OF HALF MOON CREEK, PENNSYLVANIA

Alan A. Adler and Laurence H. Lattman
Dept. Geology, The Pennsylvania State University, University Park, Pa.

The sediments underlying part of the flood plain of Half Moon Creek, Centre County, Pennsylvania, were studied by taking auger samples from holes 15 feet apart on a square grid. The topography of the flood plain was mapped with a contour interval of 0.2 foot, revealing two flood-plain channels on either side of, and approximately parallel to, the present stream. The stream is 10 feet wide, and the flood plain is 400 feet wide in the study area.

Three basic sediment types were distinguished: A_1, which contains more than 55 per cent clay and silt, and no gravel; A_2, which contains less than 55 per cent clay and silt, and no gravel; and B, which contains gravel. Lateral accretion was composed of gravel (type B) overlain by type A_2, and overbank deposits were composed of types A_1 and A_2. The finest overbank deposits (vertical accretion) occurred in the flood-plain channels. The amount of gravel increases toward the bottom of the valley fill and close to the valley sides.

The flood-plain channels approximately overlie channel-like lows in the bedrock beneath the flood plain. It is suggested that the very fine vertical accretion deposited in the flood-plain channels exerts a strong influence on the present position of the creek.

Although there was a continuous gradation from gravel to the finest sediment, lateral accretion could be distinguished from overbank deposition except for the sandy sediment type A_2. Lateral accretion constituted about two-thirds of the flood-plain sediments.

ELECTRON-PROBE IDENTIFICATION AND ANALYSIS OF SMALL MINERAL GRAINS

Isidore Adler
U. S. Geological Survey, Washington, D. C.

The electron-probe microanalyzer, designed originally by Castaing (1951) for metallurgical applications, is also a very powerful tool for mineralogical investigations. The microprobe has been applied to compositional analysis of natural and synthetic grains less than 100 microns in diameter and can be used on particles as small as 10 microns across. The analyses of individual phases in very fine-grained aggregates are easily possible.

Quantitative data obtained on a mineral inclusion about 30 microns in diameter, optically similar to valleriite, have shown it to be an as yet undefined iron sulfide with the tentative formula FeS. A similar study was made of two adjacent mineral grains 100 microns across tentatively identified optically as safflorite and loellingite. The analyses showed both grains to have a composition corresponding to FeS_2.

The microprobe is also being applied to the analysis of fine synthetic mixtures from phase-equilibria studies, exsolution particles, and compositional variation in natural zoned crystals.

The electron microprobe can be used for the elements of atomic number 12 and greater. Carefully

prepared polished sections are required, and in our present equipment the grains must be identifiable in reflected light. The lower limits of concentrational sensitivity are of the order of 0.1 weight per cent, which corresponds in some instances to absolute amounts of the order of 10^{-11} grams. Analytical results may be obtained which are accurate to within a few per cent of the amount present.

RELATIONSHIPS BETWEEN THE MINERAL ASSOCIATION, CHEMICAL COMPOSITION, AND PHYSICAL PROPERTIES OF THE CHLORITE SERIES

Arden L. Albee
Division of Geological Sciences, California Institute of Technology, Pasadena, Calif.

Relations between the mineral association, chemical composition, and optical properties of more than 200 analyzed chlorites are shown graphically. Chlorite from iron formation commonly has a high Fe/FM (= $Fe^t + Mn + Cr/Fe^t + Mn + Cr + Mg$) value; chlorite from mica schist, greenstone, and amphibolite an intermediate value; chlorite from talc, serpentine, high-Al, and high-Cr associations a lower value; and chlorite from carbonate rock and albite pegmatite in serpentinite a very low value. Chlorites of other associations show no distinct range. Chlorite from high-Cr associations and many septechlorites have a distinctly low-Al content.

The Fe/FM value of chlorite from most associations may be determined from the β refractive index with an estimated standard deviation of ± 0.05. Chlorite of most associations changes sign at a β index of about 1.630 and an Fe/FM value of 0.52. Chlorite with β greater than about 1.630 has a higher iron content, a negative optic sign, is length slow, and displays abnormal violet or blue interference colors near the sign change. Chlorite with β less than about 1.630 has a lower iron content, a positive optic sign, is length fast, and displays abnormal brown interference colors near the sign change. Birefringence increases with both increasing and decreasing refractive index away from the sign change. In routine petrographic work the optic sign and interference colors may be used to estimate Fe/FM for most associations. However, chlorite from amygdules and veins in mafic igneous rocks deviate from these generalizations. The Al content of chlorite cannot be estimated from the optical properties but can be approximated from $d(001)$.

DISTRIBUTION OF AGES IN THE ARABIAN SEGMENT OF THE AFRICAN SHIELD

L. T. Aldrich and Glen F. Brown
Dept. Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D. C.; U. S. Geological Survey, Washington, D. C.

Rb–Sr and K–Ar ages of micas from granitic rocks collected as part of a survey of the Arabian part of the African Shield have been determined. The ages fall quite naturally into two groups—one for rocks north and east of the Nadj fault; the other for those south and west of the fault. The pattern of ages west of the fault is not unlike that found for biotite samples analyzed from the Precambrian of the Appalachians with the Rb–Sr age consistently greater than the K–Ar age. The Rb–Sr and K–Ar ages of samples east of the fault are in agreement at about 580 m. y. The pattern of ages west of the fault is consistent with a period of mineralization at 1000 m. y. and subsequent metamorphism at about 400 m. y.

Of interest in defining the absolute time scale of the Paleozoic are the ages found for the granite at Jabal Salma. This granite is unconformably overlain by the Saq sandstone, which contains trilobite tracks, is definitely pre-Silurian, and is unmetamorphosed. The biotite in the granite at Jabal Salma gave ages as follows:

Rb–Sr = 590 m. y.; K–Ar = 580 m. y. with errors of 5 per cent or less in the analytical results.

COAL RESOURCES OF COLORADO

Thomas Allen and Edward L. Clark
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Colorado coals include subbituminous, semibituminous, bituminous, and anthracite. All classes have been produced commercially. Coal has been mined in six major and four minor fields or districts, as follow: the Green River field, the Uinta region, the San Juan River region, the North Park field, the Denver Basin region, the Trinidad field, the Canon City field, the South Park field in Park County, the Middle Park field in Grand County, and the Tongue Mesa field near the common corners of Montrose, Ouray, and Gunnison counties. Anthracite occurs in proximity to Tertiary intrusive rocks and is therefore limited in areal extent but is locally quite important. Coal occurs in the Upper Cretaceous, Paleocene, Eocene, and Miocene.

The reserves underlie more than 25,000 square miles, nearly one-fourth of the State. The gross reserves of all kinds of coal exceed 500 billion tons, although the more conservative estimate of 200 billion tons of recoverable coal in beds from 2 to 60 feet in thickness is more realistic. These estimates include all coal beds to a maximum depth of 6000 feet.

Production in 1959 from 130 mines was 3,294,686 tons; the maximum production of 12,500,000 tons was achieved in 1918. The past and present markets and current interest and developments indicate coal will be of increased significance in the future economy of Colorado.

CLAY MINERALS IN BAUXITE DEPOSITS OF EUROPE

Victor T. Allen
Department of Geology and Geological Engineering, Saint Louis University, St. Louis, Mo.

Bauxite and aluminous laterite deposits of France, Hungary, Yugoslavia, Greece, Italy, Spain, Germany, and Northern Ireland were studied under a National Science Foundation grant in 1957. In all deposits examined, clays composed of kaolinite and locally some montmorillonite minerals occur in association with bauxite minerals and suggest that clays were the source materials of the bauxite. Refractory ceramic kaolinite clay and boehmite from Missouri are similar megascopically and mineralogically to specimens collected in France and Yugoslavia; also, diaspore specimens from Missouri can be duplicated in the diaspore deposits of Greece. The aluminous laterites of Germany and Northern Ireland derived from basaltic rocks are similar to those of Oregon.

The commercial bauxite of France, Yugoslavia, Italy, Greece, and Spain fills solution pockets in dolomitic limestones. Kaolinite-boehmite diaspore deposits of Missouri and bauxite in Georgia fill pockets in dolomitic limestones formed by ground-water solutions. Clays and alumina hydrates were transported from suitable source areas in Europe and the United States and were deposited in cavities prepared by solution. Magnesium bicarbonate carried by ground water removed silica from clay to form alumina hydrate minerals. Observations in Georgia, Alabama, Arkansas, Oregon, and Washington suggest that desilication of clays can form bauxite.

PREFERENTIAL STAIN OF BERYL

Sarkis G. Ampian
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The U. S. Bureau of Mines has developed a laboratory method for staining beryl preferentially in +325 mesh mixtures.

Mixtures are etched in 5 ml of 0.75 per cent sodium hydroxide solution in a nickel beaker, and the solution is then evaporated to dryness and removed after complete fusion of the sodium hydroxide, over a Meker burner. The residue is leached with distilled water and washed thoroughly on What-

man 41 H filter paper. The grains are then washed from the paper into a 50-ml beaker with 5 ml of distilled water. Approximately 0.03 gram of quinilizarin is added, and the solution is made alkaline with 3 drops of 5 per cent sodium hydroxide. The resulting solution is covered and boiled for 1 minute. The beryl grains can be detected readily, as they are stained an intense blue, and quartz, feldspars, and other gangue minerals either are not stained or are pale reddish.

GENESIS OF THE SPILITE-KERATOPHYRE ASSOCIATION (PROGRESS REPORT)

G. C. Amstutz
Missouri School of Mines, Rolla, Mo.

The study of about 80 additional occurrences of spilitic-keratophyric rocks and associated ore deposits has resulted in partly new evidence and conclusions.

There is ample geometric (structural) evidence for a primary origin of many spilite-keratophyre occurrences. The original criteria and most of the ideas first offered by Benson in 1914 appear to be correct. He used congruency between primary structures and distinct mineral assemblages as genetic evidence. Albitic and carbonatitic portions and iron oxides, etc., occur in distinct primary geometric elements of the rock. Transitions and contacts used as proof of metasomatism are ambiguous; if interpreted as originating from contemporaneous transitions (of conditions and compositions in space and time) and not as epigenetic introductions of Na, etc., less assumption is required. The concept of the spilites being a "sodic igneous association" has mostly resulted from inadequate sampling.

The occurrence of intrusive and continental spilites and keratophyres suggests that submarine extrusion is not necessarily a prerequisite for spilite genesis. The causes for spilite formation must be more fundamental. A close comparison of geometric (structural and textural) evidence with experimental data on OH^{-1} and F^{-1} behavior in silica melts and glasses suggests that ordering processes in the melt such as the Al–OH ordering, induced or enhanced by high volatile contents, may be the main factor leading to primary differentiates typical in spilitic-keratophyric rocks. This evidence also supports a similar thesis of Ringwood (1959) for the genesis of the basalt-trachyte association.

GEOMETRIC CRITERIA FOR DEUTERIC MINERALIZATION IN THE MICHIGAN COPPER DEPOSITS

G. C. Amstutz and P. Dorai-Babu
Missouri School of Mines, Rolla, Mo.

Various authors suggested recently a "convergence" between epigenetic-hydrothermal, syngenetic-hydrothermal or deuteric, and metamorphic-hydrothermal phenomena, which seems to deprive physicochemical investigations of much of their genetic meaning. Whereas there may be physicochemical convergences and similarities, it is hardly conceivable that the geometry of the mechanics of these processes could be the same. Each process has its own symmetry.

The resolution of the impasse of geochemical convergences is therefore careful studies of the geometric patterns in rocks and mineral deposits, in particular of the symmetry of mineral distributions (zoning, fabrics, etc.). Unbiased approaches require purely descriptive, connotation-free concepts and terminologies. A useful, purely geometric concept is that of congruency. The statistical distribution of congruent and noncongruent features in rocks and mineral deposits as well as common sense suggests that congruency is a valuable genetic criterion.

Detailed observations in the copper ores of the Michigan lavas revealed excellent congruency between symmetry and space of the rock-forming processes on one hand and the mineral distribution on the other hand. The small- and large-scale congruency between the mineral distribution and the

following primary features excludes later introduction and supports a deuteric age of both the copper and the associated minerals, as well as of many rock-forming minerals: (1) different breccia fragments, (2) breccia fragments and matrix, (3) various interpenetrating generations of lava, (4) flow features, (5) top-bottom features, (6) amygdules, "steam-pipes", etc.

EVIDENCE OF SEASONAL LAMINATION

Roger Y. Anderson
University of New Mexico, Albuquerque, N. Mex.

Most laminated sediments are varves, and seasonal deposition can be demonstrated in several ways: (1) Microtome sectioning and pollen study of clastic laminae reveal seasonal changes in pollen and spore content; such a study of the mid-Pleistocene Channing lake silts of Texas was practicable for laminae 1 mm thick. (2) Statistical comparison of thickness-change patterns with known climatic patterns; (3) Autocorrelation analysis of thickness changes to reveal the 11-year sunspot period or its multiple; a study of a Devonian shale found a significant 22-year period. (4) Theoretical estimates of annual precipitation of chemical laminae such as calcite, dolomite, anhydrite, and halite. (5) Direct observation of deposition and clastic increment studies of recent sediments. (6) Interlamination with known seasonal deposits.

An outstanding feature of seasonally deposited laminae is variation in thickness. One standard deviation is usually greater than half the value of the mean thickness and may be more than 80 per cent in some clastic laminae but can be less than 30 per cent in some evaporite and glacial laminae.

Laminae that exhibit lateral persistence are set off by an organic layer or chemically precipitated layer, whose average thickness is on the following order of magnitude: calcite and dolomite, less than 1 mm; anhydrite, 2–7 mm; halite, 2–8 cm; clastic (all types) laminae 0.1 mm–5 cm thick can generally be considered the result of seasonal deposition unless evidence suggests otherwise.

RECONNAISSANCE GEOLOGY OF THE MT. NUSSBAUM AREA, TAYLOR DRY VALLEY, VICTORIA LAND, ANTARCTICA

E. E. Angino, M. D. Turner, and E. J. Zeller
University of Kansas, Lawrence, Kans.; National Science Foundation, Washington, D. C.; University of Kansas, Lawrence, Kans.

The Mt. Nussbaum area in the central part of Taylor Dry Valley consists of a thick, nearly vertical sequence of metasedimentary rocks in sharp contact on the west with banded granitic rock. More than 3000 feet of marbles, schists, and quartzites was mapped. Granitic banding parallels the strike of the metasedimentary series and may represent relict bedding.

Four lamprophyric dike systems, striking east, northeast, east-northeast and northwest respectively, cut the granitic and metasedimentary rocks. Pegmatitic and aplitic veins (and dikes) intrude granitic rocks and, in places, the metasedimentary rocks.

Much of the area is blanketed by morainal material deposited by Taylor Glacier and its tributaries. At least one glacial advance overrode the crest of Mt. Nussbaum. Eastward movement is indicated by chatter marks and grooves. The youngest glaciation in the area is indicated by four fresh morainal systems in front of alpine glaciers draining south out of the Kukri Hills. West of Mt. Nussbaum some of the late moraines are covered by basaltic cinder cones and small flows. Basalt is present on the second of the four late morainal systems but not in the first. The third and fourth morainal systems include some basalt and, in places overlie the older flows and cones. The basaltic upwelling seems to have occurred between the first and second advances of the late major glaciation. Later eolian erosion has resulted in extensive deflation and scattered sand dunes.

REGIONAL ASPECTS OF THE MONONGAHELA SERIES OF THE APPALACHIAN BASIN

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West Virginia Geological and Economic Survey, Morgantown, W. Va.

The Monongahela series of Pennsylvania, West Virginia, Ohio, and Maryland includes cyclically alternating sedimentary units. Gross lithology shows Red, Transitional, and Gray facies from south and southwest to north and northeast. Well-preserved leaf and stem impressions, footprints, and fossils of amphibians and reptiles are in the Red and Transitional facies, while a fresh-water invertebrate fauna (ostracods, *Estheria*, occasional pelecypods, and gastropods), insects, worm markings, and fish remains are principally in the northern Transitional and Gray facies.

The ideal cycle of deposition, which is composed of coals, shales, thin-bedded to massive sandstones, mudstones, limestones, and clays, is best developed, locally, in the gradational zone between the Gray and Transitional facies. Units of the Gray facies intertongue to the south and southwest with oxidized fine clastic rocks and massive sandstones in the Transitional facies. Gray shales grade to mottled red and yellow shales, thin-bedded sandstones alternate with thick massive sandstones, and coals thin and become less pure. Carbonate sequences thin to single beds and finally grade into discontinuous nodular zones embedded in mottled red and yellow shales. Farther south, the thin and poorly developed coals and limestones of the Transitional facies disappear laterally into oxidized nondescript red and yellow shales and gray sandstones of the Red facies. Gradual intertonguing of the Red, Transitional, and Gray facies records the slowly shifting continuous encroachment of more terrestrial clastic sediments northward into the lake-swamp environment (Gray facies) during the deposition of the Monongahela series.

MISSISSIPPIAN SYSTEM OF SOUTHWESTERN NEW MEXICO AND SOUTHEASTERN ARIZONA

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The Mississippian system of the area is represented by 600 and 1200 feet of dominantly carbonate rocks, separated from the upper Devonian by a paraconformity and from the overlying Pennsylvanian by an unconformity. Oldest sequences are the basal beds of the Escabrosa limestone, which are Osagian limestones containing the following corals: *Lithostrotionella, Homalophyllites, Rylstonia, Kakwiphyllum, Vesiculophyllum*; brachiopods: *Unispirifer* sp., *Spirifer gregeri, Beecheria chouteauensis*; and blastoid: *Cryptoblastus melo*. This sequence is continuous with the Andercito-Alamogordo members of the Lake Valley formation and the Represo limestone of Sonora, Mexico. Sedimentation was essentially continuous throughout Osage Meramec time in the Escabrosa basin. Terrestrial clastic rocks are virtually absent, and the predominant rock type is encrinite. The fauna consists of the following diagnostic assemblages in ascending order: Fern Glen:—*Unispirifer forbesi, Leptaena analoga, Amplexizaphrentis* sp.; Burlington:—*Unispirifer forbesi, Amplexizaphrentis* sp.; Keokuk:—*Vesiculophyllum, Pentremites elongatus*; Warsaw:—*Unispirifer lateralis, Spirifer bifurcatus, Syringothyris subcuspidatus, Beecheria formosum, Werriea keokuk*; St. Louis–St. Genevieve:—*Eumetria verneuilliana, Dielasma bisinuata*. The Chesterian Paradise formation is confined to extreme southeastern Arizona and southwestern New Mexico and consists of an alternating series of thin-bedded shales and limestones with a maximum thickness of 230 feet, ranging in age from very late Meramec to middle Chester. The Chesterian Helms formation of the Franklin Mountains, west Texas, and the Sacramento Mountains, central New Mexico, is an eastward facies of the Paradise formation. The Helms formation contains the locally abundant corals, *Dibunophyllum bipartitum koninckı* and *Koninckophyllum* sp.

LEAD-ISOTOPE VARIATIONS WITHIN A SINGLE CRYSTAL OF GALENA

Carl F. Austin and William F. Slawson
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Small compositional variations of lead isotopes in the Hansonburg mining district, New Mexico, are greater than experimental errors. In searching for a possible explanation of this, the isotopic composition of a single crystal was examined in detail. At a sample site in the district half a cube of galena measuring 2.5 by 2.3 by 2.2 inches was collected.

This crystal was cut with a diamond saw into cubes measuring about 0.5 inch on a side. Three such cubes, the corner (1, 1, 1), the center (2, 2, 2), and the innermost (3, 3, 3), which were diagonally adjacent, were analyzed isotopically.

	Pb 204	*Pb 206*	*Pb 207*	*Pb 208*
Corner (1, 1, 1)	1.284	27.15	20.47	51.08
Center (2, 2, 2)	1.245	27.83	20.06	50.87
Innermost (3, 3, 3)	1.256	27.74	20.14	50.87

The corner (1, 1, 1) has a composition distinctly different from the others.

Another such sample cube (2, 1, 1), which had two outside faces, was itself cut into three portions and analyzed.

	Pb 204	*Pb 206*	*Pb 207*	*Pb 208*
Outer surface (2, 1, 1-A)	1.292	26.99	20.48	51.24
Just beneath outer surface, 2, 1, 1-A (2, 1, 1-B)	1.257	27.77	20.08	50.89
Remainder of cube (2, 1, 1-C)	1.254	27.76	19.99	51.00

The last group of analyses indicates that the isotopic variation within the single crystal is definitely a "skin" effect.

"REPLACEMENT" BY GRAIN CAVITY FILLING*

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Study of the Jurassic upper Morrison sandstones of McKinley and Valencia counties, New Mexico, suggests that many features commonly attributed to replacement are actually the result of filling of solution cavities in detrital grains. In poorly cemented and porous zones, solution has produced numerous hollow shells of detrital grains, which frequently contain feldspar remnants and/or authigenic minerals. However, in calcitic zones, almost exact counterparts of these shells, filled with calcite, strongly resemble features from other localities and stratigraphic units, which have been ascribed to "replacement", an interpretation which is thus open to question.

Criteria for deciding, in every instance, between the two processes are lacking. Criteria suggesting direct replacement are: (1) guest idiomorphic against remnant of host grain; (2) remnants of host "floating" in guest. Criteria suggesting cavity filling are: (1) unfilled cavities in grains appearing to be partly replaced; (2) unfilled cavities in similar grains nearby; (3) delicate remnants displaced relative to remainder of host; (4) two guest minerals—one, not an intermediate phase, coats detrital

* Publication approved by the U. S. Atomic Energy Commission

grains, outlines vanished grains, and coats some remnants of hosts; the other occupies all other available space. Additional criteria are needed and probably can be developed.

PLEISTOCENE FLORAS FROM THE CHAGOOPA SURFACE, SOUTHERN SIERRA NEVADA

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Spore-pollen floras from sediments of three lake basins on the Chagoopa surface of the Kern Plateau are dominated by trees that make up the moist, temperate Yellow pine and Fir forests of northern California and adjacent Oregon. Species of the Coast and Subalpine forest zones are also present.

Spore-pollen floras from sediments on quartz diorite basement at Alabama Hills and Little Lake at the base of the Sierra Nevada in Owens Valley also represent vegetation like that now constituting the ecotone between Yellow pine and Fir forest in northern California, and species of the Coast and Subalpine forests are represented.

At the time of deposition the floras now in Owens graben had approximately the same altitude as those on the Kern Plateau: all of them display similar altitudinal relations in terms of modern vegetation zones. The erosion surface in the graben at Alabama Hills and Little Lake on which the sediments rest must therefore be the displaced counterpart of that which is now perched high on the Sierran scarp above Owens Valley, and which extends across the Sierran summit divide as the Chagoopa surface.

Since the floras were contemporaneous with the first (McGee-Glacier Point) glaciation in the Sierra Nevada, which appears to be Kansan, it is concluded that post-Kansan displacement of the Chagoopa surface on the Sierran scarp below Mount Whitney amounts to 6000 feet, that on the scarp above Little Lake to 3000 feet.

CYCLIC DEPOSITION OF THE CHEROKEE GROUP IN THE SUBSURFACE OF SOUTHEASTERN KANSAS AND NORTHEASTERN OKLAHOMA

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During a study of the origin of petroleum in the Cherokee Basin of southeastern Kansas and northeastern Oklahoma two complete stratigraphic sections of the Cherokee group (Desmoinesian) have been compiled from cores from wells located 90 miles west of the outcrop limit of the Cherokee group.

The Cherokee group in both sections is divisible into a number of cyclothems composed of nonmarine and marine facies. Specifically, the lower part of each section is characterized by cyclic deposition involving a large proportion of nonmarine facies, such as underclay and coal; the upper part is characterized by the cyclic deposition of predominantly normal marine sediments, such as fossiliferous gray, greenish-gray, and black shale with some limestone; the middle part records the transition from dominantly nonmarine to marine deposition and is characterized by shore-line facies.

Correlation of specific members such as the Excello shale, Breezy Hill limestone, and Verdigris limestone between the surface and the subsurface is evident. However, in the upper part of the Cherokee group, the proportion of marine facies is greater, and the cyclothems are less well developed in subsurface sections than in the outcrop area. It is suggested that the upper Cherokee group in the outcrop area was deposited on a uniform broad shelf but that subsurface equivalents were deposited in a

slightly deeper part of the Cherokee Basin where minor oscillations of sea level were less effective in changing the pattern of deposition and causing the development of obvious cyclothems.

DISTRIBUTION OF HYDROCARBONS IN CRUDE OIL

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The cumulative frequency distribution of concentrations of hydrocarbons in crude oil has been investigated. It was found that most hydrocarbons in the gasoline range of petroleums have either a homogeneous or heterogeneous (bimodal) log-normal distribution. All of the very water-soluble hydrocarbons (C_8 and below), however, are normally distributed. An explanation of the genesis of both the normal and log-normal distributions in terms of the hypothesis that crude oils consist of hydrocarbons that collected from waters containing natural solubilizers is presented.

It appears that the distribution of hydrocarbons in crude oil simply reflects the polydispersity of the micelles in which hydrocarbons selectively dissolve. The subsequent release of the solubilized hydrocarbons from micellar solution results in the formation of crude-oil droplets. Such a geochemical process of oil formation explains not only the characteristic distribution of certain homologous and isomeric hydrocarbons present in a particular crude oil but also accounts for the statistical nature of the variation in their absolute amounts from one crude oil to another.

Analysis of the cumulative frequency distribution also permits the composition of a "typical" petroleum to be defined for the first time. The composition of API Research Project 6 crude oil is discussed in the light of this definition.

ALKALIC ROCKS AT LITCHFIELD, MAINE

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A pluton of sodic syenites and nepheline syenite, oval in outline and 2 miles in greatest diameter, cuts granulite and schists at Litchfield in south-central Maine. Emplacement was by forceful intrusion, deflecting the strike of the vertically dipping metasedimentary rocks; stoping of small blocks was a minor process. The Litchfield intrusive is probably a member of the White Mountain magma series, judging from lithology and post-orogenic emplacement. If correlation with the alkalic rocks of New Hampshire is valid, then the Litchfield pluton is the easternmost known representative of the series and was emplaced at considerably greater depth than the others.

The type "litchfieldite", described from glacial erratics by Bayley in 1892, is a medium granular to pegmatitic albite-rich nepheline syenite, containing about 50 per cent albite, 25 per cent microcline, and 20 per cent nepheline. Iron-rich biotite (lepidomelane) is the only mafic mineral in the type rock, which is a rather minor and aberrant portion of the intrusive. Coarse to fine nepheline-free syenites have the same albite to K feldspar ratio as the litchfieldite, but the mafic minerals are lepidomelane, lepidomelane plus magnetite, magnetite, acmite plus a sodic amphibole having the optical properties of arfvedsonite, acmite plus magnetite plus lepidomelane, or amphibole plus lepidomelane. Variations in the mafic mineral assemblage, which rarely exceeds 5 per cent of the rock, are attributed to variations in P_{H_2O} and P_{O_2} in the magma. Reaction of magma with inclusions of metasedimentary rock locally produced quartz syenite.

COAL-BEARING STRATA OF THE MATANUSKA COAL FIELD, ALASKA

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The coal-bearing Chickaloon formation, of early Tertiary age, underlies an estimated 200 square miles in the Matanuska Valley of south-central Alaska. It is best known in the Wishbone Hill district,

where extensive development by underground and strip mines has given maximum opportunity for study.

The coal-bearing rocks, with a total thickness of at least 3000 feet, are believed to consist chiefly of fluvial and delta deposits. They include all textural gradations from claystone to coarse sandstone and some conglomerate. The sandstones are notably feldspathic.

Rapid lateral variation in both lithologic character and thickness is characteristic of the Chickaloon formation. Such variation occurs not only in individual beds, including the coals, but in larger units or coal groups that comprise several closely spaced coal beds separated by thick barren strata.

The Chickaloon formation, although now limited largely to the floor of the Matanuska Valley, which is a structural trough of later origin, probably once extended beyond these limits into present mountainous areas. Lithologic characteristics of pebbles suggest a source to the north. Evidence indicates deposition under humid temperate climatic conditions on a broad alluvial plain that remained close to sea level. No evidence of marine deposition has been found.

SPHALERITE SOLUBILITIES IN SULFIDE SOLUTIONS

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The solubility of ZnS has been determined in portions of the systems ZnS–H_2S–H_2O, ZnS–H_2S–H_2O–S, and ZnS–H_2S–H_2O–NaOH. No geologically stable complexes of the types $ZnS \cdot xH_2S$ or $ZnS \cdot \gamma H_2S_x$ were found at equilibrium in either aqueous or immiscible H_2S_x liquids to over 200° C. and 40 atm. However, solubilities of ZnS up to 2.70 ± .05 g./L. (pH ≈ 8.2, 85 p.s.i., 25° C.) have been determined in aqueous bisulfide solutions. The reaction

$$ZnS(s) + HS^-(aq.) \rightleftarrows ZnHS_2^-(aq.)$$

describes the data obtained for pH values of 4.–8.2, $P_{H_2S} < 1$–28. atm. and 25–195° C. At an ionic strength of 1.6, the effective equilibrium constant is $(1.00 \pm .25) \times 10^{-3}$ at 25° C., and it is essentially constant to 195° C.

This bisulfide complex is sufficiently stable to account for ore transport at low temperatures in neutral to moderately alkaline solutions having high (HS^-) activities. Possible causes of deposition are oxidation, decrease in P_{total}, or decrease in pH, but not simple dilution or decrease in temperature.

Studies of rates of reaction indicate that equilibrium in the reaction $H_2S(g) \rightleftarrows H_2S(aq.)$ is approached very slowly. The rate is first order: $(dP/dT) = K(P_t - P_\infty)$ where $K = (1.8 \pm 0.3) \times 10^{-2}$ hours^{-1} (for P in p.s.i. and t in hours) for an agitated system. However, the rate of equilibration of the complex is rapid. Under geologic conditions, metastability might be expected in the evolution of $H_2S(g)$ from an ore solution where P_{total} is decreasing; nevertheless, deposition of sphalerite, if from this complex, would be an equilibrium process.

ROLE OF CHEMICAL POTENTIAL OF SULFUR IN CONTROLLING MINERAL ASSEMBLAGES IN SULFIDE DEPOSITS

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For a given bulk composition of metals the sulfide assemblages in most mineral deposits are determined by two primary variables, temperature and chemical potential of sulfur. Total pressure can almost be neglected. A diagram in which chemical potential of sulfur is plotted against temperature thus provides a generally applicable frame of reference for most hydrothermal deposits. This grid is useful in interpreting the paragenetic and zoning relations in ore deposits and is particularly helpful in the application of the sphalerite geothermometer to pyrite-sphalerite assemblages.

The hypogene zoning in the Central City district, Colorado, is reflected by a change in composition of sphalerite as well as by changes in gross mineralogy. The over-all pattern is interpreted as having formed from solutions which initially were at a temperature of the order of 600° C. and cooled to 300°–400° C. as they moved upward and outward. As cooling progressed the chemical potential of sulfur dropped so slowly that more sulfur-rich assemblages were deposited peripherally. Presumably the chemical potential of sulfur changes through homogeneous reactions in the ore fluid, for there is no indication of extensive reaction with wall rock at this stage. The rate of change of chemical potential of sulfur with temperature followed two trends and led to the formation of two assemblages: (1) pyrite-galena-tennantite-chalcopyrite-sphalerite, and (2) pyrite-galena-tennantite-enargite-sphalerite. Sphalerite (1) contains much more FeS than (2).

OCCURRENCE OF 1000-MILLION-YEAR-OLD MINERALS IN EASTERN UNITED STATES AND CANADA

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New Rb–Sr and U–Pb age measurements show that minerals with ages in the 900–1150 million-year range occur in rocks from an area considerably larger than that previously known. This area is outlined from the Grenville front in Quebec along the Appalachians to Tennessee, and from Georgian Bay southwest and south through Michigan and Ohio to West Virginia. Material from drill holes through the sedimentary rocks into the basement was used in Michigan, Ohio, and West Virginia. The 1000 million-year ages define an area comparable to that shown by 1350 million-year ages in the western United States and indicate the extent of igneous intrusion and metamorphism 1000 million years ago in the eastern United States and Canada.

K:AR AGES, MARYSVALE, UTAH—TERTIARY VOLCANIC ROCKS*

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The Tertiary flows and intrusives of the Marysvale, Utah, area yield a diversity of materials that contain potassium and provide a geologically unique locality for the application of the potassium-argon method. A layer-by-layer sequence of potassium-bearing mid-Tertiary flows and tuffs of the Bullion Canyon series overlies fossil-bearing Oligocene sedimentary strata of the Wasatch formation. The series is invaded by quartz monzonite, which contains potassium-bearing biotite. A sequence of late Tertiary volcanic rocks, the Mt. Belknap series, contains potassium-bearing fresh volcanic glasses and rests upon an old erosional surface, which truncates both the Bullion Canyon series and the quartz monzonite intrusives. Late Tertiary uraninite-bearing veins cut the quartz monzonite and form lenticular masses at the base of the Mt. Belknap, thus providing a source for uranium–lead determinations in the late Tertiary.

Potassium-bearing materials used thus far are sanidine, biotite, and glasses. The geological control of the specimens studied has been based on the published geologic map of the Marysvale area (Kerr *et al.*, 1957), and the age determinations have been made at the Chemistry Department of the Brookhaven National Laboratory.

The absolute ages (m.y.), materials, and formational units for some of the significant specimens are:

Mt. Belknap Volcanic Series:
KA 34 glass: Gray phase, N. of Antelope Canyon, 15.2
KA 15 glass: Base of the gray phase, Deer Canyon, 16.0
KA 31 glass: Base of the gray phase 1 mile NW. of KA 14, 16.5

* Research performed under the auspices of the U. S. Atomic Energy Commission

KA 14 glass: Black knob 2 miles N. of Marysvale on US 89, 18.4
KA 28 glass: Gray phase near mouth of Beaver Creek, 19.0
Quartz Monzonite:
KA 2 biotite: Prospector Mine, 27.8
KA 11 biotite: Mineral Hill prospect, 25.1
Bullion Canyon Volcanic Series:
KA 7 sanidine: Newlyweds prospect, 28.0

SEASONAL FACTOR IN THE ECOLOGY OF PLANKTONIC FORAMINIFERA

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Surface plankton tows collected during 1959 and 1960 at Weather Stations Bravo (56.5° N., 51° W.), Charlie (53° N., 36° W.), Delta (44° N., 41° W.), Echo (35° N., 48° W.), and Bermuda by the United States Coast Guard have made possible studies of seasonal variations in the species composition of living populations of planktonic Foraminifera in a 4000-mile arc from the Labrador Sea to the north-central Sargasso Sea.

Station B (Bravo) is populated by a homogeneous, subarctic foraminiferal fauna (2 species). Stations C and D are dominated by the same two subarctic and three cold-temperate species, although warm-temperate and subtropical species do appear during the warmer months. The most striking seasonal variations occur at E and off Bermuda, where cold-temperate species similar to those at C and D flourish during winter and spring, and subtropical species (4 species) replace them with little time overlap during summer and autumn. A warm-temperate group of seven species is present throughout the year at E and Bermuda.

It is not certain whether the cold-temperate and/or subtropical faunas in the northern Sargasso Sea are (1) autochthonous populations, having separate augmentation seasons, or (2) allochthonous populations, transported by water masses from different oceanic regions.

Whatever the cause of their seasonal succession, the fact that various planktonic foraminiferal species appear in the same geographic locality during alternating seasons indicates that species with different ecological tolerances can eventually occur together in the same local bottom sediments.

BIOASSAY OF ORGANIC MICRONUTRIENTS WITH A MARINE BACTERIUM

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Bacterial gene mutations, resulting in inability to synthesize specific biochemical end products, can be induced by ultraviolet irradiation. This discovery suggested the possibility of establishing a sea-water bioassay based upon the use of such mutants. A marine bacterium, *Serratia marinorubra*, was selected as a possible bioassay organism. Given a mixture of inorganic salts with glycerol as its energy source, this organism is capable of synthesizing every biochemical compound it requires for growth. Exposure of *Serratia* to ultraviolet light has so far resulted in selection of about 110 different biochemically deficient mutants, with requirements for at least 17 different compounds.

As mutants with new requirements were isolated, they were incorporated into the bioassay procedure. Sea-water samples, supplemented with glycerol, are delivered into triplicate sets of tubes. These tubes are inoculated with the mutants separately. Since the mutants will not grow in the absence of their required specific end product, growth in a given set of tubes indicates the presence of that end product in the water sample. Furthermore, the amount of growth is proportional to the concentration within defined limits.

Application of the bioassay to sea-water samples has demonstrated the presence of a variety of biochemical compounds in the sea. Most surprising has been the frequent occurrence of Isoleucine. Other amino acids, as well as vitamin and nucleic-acid base activity, have also been found.

This technique shows promise for both qualitative and quantitative characterization of some of the soluble organic materials in sea water.

MINIMUM STANDARDS FOR ACCREDITATION OF GEOLOGICAL CURRICULA

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If accreditation is to be considered by our several professional organizations, the National Association of Geology Teachers must become informed in regard to previous publications on accreditation and the related area of curriculum, as well as in regard to what has been done in other fields, *e.g.*, Chemistry and Engineering.

Publications relating to geological curricula and accreditation over the past 40 years were compiled in an annotated bibliography and form the basis for this presentation. Many consist of a survey of what is offered at different schools. Others recommend maximum rather than minimum standards; the problem then is to condense such curricula into a 4-year program.

Professional standards and objectives must be determined before a curricula can be devised to meet these standards and objectives. Moreover, a reasonable set of minimum standards, applicable to all potential geologists, would avoid the proliferation of specialized courses on the undergraduate level and would help to remedy the deficiencies in fundamental and basic courses so evident in the preparation of many geology graduates today.

STRUCTURE OF THE WIND RIVER MOUNTAINS, WYOMING

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The Wind River Mountains are a northwest-trending asymmetric anticline that exposes Precambrian crystalline rocks along a core 120 miles long and 25 miles wide. The northeast flank dips uniformly an average 10° into the Wind River Basin, but structural relations on the southwest flank are obscured by Tertiary sediments of the Green River Basin which overlap the Precambrian core. Seismic profiles show that the southwest flank is bounded by a thrust fault which dips 18° NE. and has a maximum throw of 35,000 feet. The structure of the Precambrian core is complex and appears to be highly faulted. Transverse faults cross the range and are well shown at the southeast end where lateral displacement is from 2 to 6 miles. The range is a positive anomaly on regional Bouguer gravity data, which suggests that the mountains have no roots. The range probably originated by compressional forces, strongest toward the southwest, which acted only upon the shallow portion of the crust. The range, therefore, is not a block uplift, a structural type previously described as typical of the Wyoming foreland.

GEOCHEMICAL ASPECTS OF COAL FORMATION AND STRUCTURE

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Recent enquiries into the formation and structure of coal, and a reappraisal of past researches in these fields, permit reasonably detailed description of the principal phases of coal diagenesis.

In this paper, attention is focused upon three "key" topics: (1) the nature of the source materials; (2) the geochemical and geophysical factors governing maturation; and (3) the relationship between coal maturity and structure.

(1) Early controversies have been largely resolved. Both lignin and cellulose (and their primary degradation products) can be converted into coal-like solids, but selection of the source material (mainly determined by ecological conditions) has a direct bearing upon the properties of the coalified product.

(2) It is suggested that the general theory, which is itself still only qualitative, possesses several unsatisfactory features, and that classical views about the effects of pressure, temperature, and time may require revision in the light of modern advances in chemical kinetics.

(3) Reorientations during the past decade have introduced several (justifiable) simplifications: applications of statistical constitution analysis, X-ray and infrared spectroscopy, and functional group analysis have led to the concept of a much less compact coal molecule than the highly condensed polynuclear structures originally envisaged. The main chemical changes in this molecule during coal maturation are traced, and the relationship between *in situ* maturation and carbonization is briefly discussed.

SIMULATION OF METAMICTIZATION IN NUCLEAR REACTORS

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Al_2O_3 and $ZrSiO_4$ show little change in properties when exposed to 10^{18}–10^{19} nvt of thermal neutrons in an atomic pile. When, however, a source of fission fragments is provided in the form of a UO_2 dispersant, the grain boundaries and the peaks of the X-ray diffraction profile disappear on irradiation. U_3O_8 and BeO behave similarly; in the case of coarse mixtures of BeO and UO_2, amorphous haloes about each UO_2 grain have a thickness corresponding to the range of fission fragments in BeO. Al_2O_3 was observed to increase about 30 per cent in volume concurrent with the destruction of its crystal lattice.

Calculations indicate that only a small proportion of the atoms are displaced by the fission fragment through elastic collisions or other applicable mechanisms. It is suggested that the fission fragments act indirectly, through anisotropic effects that distort the lattice and render it unstable. Observations made on quartz support this hypothesis. If the mechanism of natural metamictization is of this nature, the degree of metamictization would not be linear with the amount of irradiation, and its usefulness for age-determination purposes is placed in doubt.

The fact that U_3O_8 is rendered amorphous extremely easily in-pile suggests that the highly oxidized uraninites ($UO_{2.6-2.7}$) giving no diffraction pattern may actually be metamict U_3O_8 or the related $UO_{2.6}$ phase. UO_2 continues to give a diffraction pattern until it is subjected to considerably greater amounts of irradiation.

TIME-SPACE RELATIONSHIPS OF THE ORES AT CREEDE, COLORADO

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A knowledge of the details of the time–space relationships among ore and gangue minerals is prerequisite to the understanding of the processes of ore genesis. To this end we have begun a detailed mineralogic study in what appears to be an ideally suited deposit: the OH vein at Creede, Colorado. (*See also* Roedder, these abstracts.)

The ores are coarse, unsheared space fillings in a tabular, nearly vertical vein that fills a minor antithetic fault within a major graben extending northward from the Creede Caldera. The wall rock

is uniform welded tuff of rhyolitic composition. Hydrothermal alteration is minor. The vein has been developed for about 1000 feet vertically and for more than a mile laterally.

The mineral assemblage includes galena, sphalerite, chalcopyrite, pyrite, quartz, hematite, and chlorite, with minor fluorite, barite, and ankerite.

Compositional zoning and several stages of alternate precipitation and leaching are recognizable in individual sphalerite crystals and can be correlated throughout most of the mine, thereby providing "marker horizons." Galena and chalcopyrite are similarly zoned and leached, and various "generations" of these minerals can be established in the time sequence by their relationships to the various "horizons" in sphalerite.

Time–space relationships in ore deposits of this type may be much more complex than is generally appreciated. Conclusions based on the assumption that equilibrium was established between phases require thorough knowledge of the detailed paragenetic relations and may be applicable only over small increments of the time sequence and short distances.

CONCEPTS OF TESTING AND GRADING IN AN ELEMENTARY GEOLOGY CLASS

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Composing, administering, and grading a test in an elementary geology class is considered a menial chore by many teachers. However, if the test is to serve as an educational device, the teacher should be closely, even personally, concerned with the test.

A balanced reasoning-essay type of examination presents problems in formulation and in grading but accomplishes both learning and testing. Reasoning through problems where the student is made to insert key numbers, so that each arrives at a different answer, is recommended. Essay questions setting up new or differing situations are also favored.

Factors to be considered in grading include, (1) judgments of relationships, (2) ability to reason, (3) knowledge of principles.

COMPOSITION OF MODERN SHELL MATERIALS

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Calcium-carbonate shell material from 10 modern organisms collected chiefly from the Bahama Island area was examined by X-ray diffraction and by orthodox chemical methods. The two means of analysis are in good agreement, showing the shell materials to contain impurity ions in solid solution. Those organisms secreting carbonate skeletons within a leathery integumen, *e.g.*, echinoids, are characterized by impure calcite plates, whereas generally the shells of organisms covered only by a periostracum, *e.g.*, clams, are aragonite.

Magnesium carbonate in solid solution is the chief impurity in the calcite samples. Chemical analysis and X-ray diffraction patterns indicate that the range of $MgCO_3$ and $CaCO_3$ is from 0 to 13 mole per cent. Variations exist between individuals of the same species collected from the same place.

The difficulty of determining Sr, Ba, and Pb in the presence of Ca prevents quantitative determination of purity in aragonite shells at this time. Some aragonite from the Bahama Island area is known to contain Sr in solid solution. Qualitative indications of Sr in aragonite and differences in diffraction patterns of the samples and a standard aragonite are shown.

Interesting differences are noted between a barnacle collected in the Caribbean area and one from Alaskan waters. The Alaskan barnacle is well-crystallized, pure calcite, and the Caribbean one is impure aragonite.

The implications of the study to sedimentary petrology and geochemistry are significant. Impure crystals may supply ions for neomineralization during diagenesis and add to our knowledge of primary deposition of certain elements from sea water.

TEACHING GEOCHEMISTRY

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The segment of science referred to as "geochemistry" does not easily lend itself to pedagogy. The difficulty stems from (1) the wide range of associated problems and research and (2) the usual heterogeneity of class background.

The burden of a course designed to complement the title "geochemistry" should be one of *integration* rather than specialization. Instruction should stress the broad aspects of the study of our environment and not stifle the imagination by specializing in areas which stress limited phases. Investigations of oceans and ore deposits, isotopes and ions should be shown to have common grounds and common goals. The gross geological aspects should not be slighted in treating the atoms, nor should the converse be true.

Tomorrow's investigators will benefit most from a course that integrates and correlates the knowledge they possess, or will possess, in the fields of chemistry and geology. The chemist must "think to scale," and the geologist must have an awareness of the manifestations of chemical laws in nature.

With such a task at hand, time should not be spent reviewing theories of ore deposition or working phase-rule problems but, rather, preparing the student to evaluate these theories and to *recognize these problems in nature*. Techniques and procedures should be left for other courses.

Subjects often artificially separated should be presented so as to emphasize the basic principles that link them in nature; in essence, magmatic crystallization, weathering, and metamorphism may be pedagogically unified through the atomic structure of silicates and their resultant stabilities.

"DRIFTLESS AREA" OF WISCONSIN WAS GLACIATED

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Isolated deposits explainable only by glaciation are on crests of the highest ridges in all but La Crosse County in the classical "Driftless area" of southwest Wisconsin.

Fresh gravel of foreign rocks, such as granite, gabbro, and basalt, is beneath thick loess in southeast Grant County. The gravel was probably deposited by meltwaters from a late Altonian ice advance (Wisconsinan stage) of about 30,000 years ago. A Carbon-14 date of 24,600 ± 1100 years B.P. (GRO-2114, courtesy of M. T. Beatty, Francis D. Hole, and Gerhard Lee) on buried soil at the base of the loess nearby implies that loess did not start accumulating until the Farmdalian substage. Coarse sand and gravel of well-rounded to angular quartz, chert, jasper, and siliceous metamorphic rocks are in kamelike deposits in many places. Well-rounded pebbles of those materials are in present soils and are intimately mixed with large angular blocks of sandstone and dolomite, with irregular masses of chert, and with clay, silt, and sand in till-like deposits many feet thick. Angular blocks of St. Peter sandstone weighing several tons are on top of Platteville limestone, which is stratigraphically above the St. Peter.

Locally contorted bedrock, absence of thick residual soils and of weathering in the deposits, and absence of old loess further confirm glaciation of much, if not all, the Driftless area during the early Wisconsinan stage or all of it during a pre-Wisconsinan stage.

UNDULATORY EXTINCTION IN QUARTZ OF IGNEOUS AND METAMORPHIC ROCKS, AND ITS SIGNIFICANCE IN PROVENANCE STUDIES OF SEDIMENTARY ROCKS

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Sedimentary petrographers have used the internal characters of clastic quartz grains (presence and degree of undulatory extinction, polycrystalline nature of grains, etc.) as indicators of the type of rock from which sediments were derived. The method has been extensively used in provenance studies. To test the validity of the method, quartz grains in more than 100 quartzose igneous and metamorphic rocks were examined and classified according to the criteria employed by sedimentary petrographers. Special attention was paid to characters generally believed to result from strain, notably undulatory extinction.

Several conclusions are justified: (1) Unstrained quartz grains are uncommon; they are present in quantity only in young plutonic rocks and metamorphic rocks, especially schists. (2) Grains with marked undulatory extinction are most common in plutonic rocks; quartz in granites is almost invariably of this type. Zones of undulatory extinction are parallel or subparallel and might yield relatively unstrained fragments by fracture along zone boundaries. (3) Polycrystalline clastic grains are probably derived from gneisses and metaquartzites.

Grains without undulatory extinction are common in sandstones and orthoquartzites; they are probably derived from schists and perhaps some gneisses. It is unlikely that granites provide these grains, as has been claimed.

The angle between extreme orientations of the c-axis in a grain with undulatory extinction, measured on a flat stage, has been used to classify such grains. These angles are significant only if measured on a universal stage.

The method is considered of dubious value, as undulatory extinction may be induced by deformation after deposition of the sediment.

PLEISTOCENE CRUSTAL AND SEA-LEVEL MOVEMENTS IN MAINE

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Late-glacial and postglacial submergence of coastal Maine resulted in the deposition of an extensive layer of gray silty clay over coastal lowlands. A radiocarbon date (W-737) of 11,800 ± 240 years B.P. has been reported from pelecypod shells in the marine sediment. Pollen stratigraphy implies that re-emergence of the coastal area, accompanied by differential crustal upwarping, was in progress 7000–8000 years ago. Re-emergence resulted in subaerial weathering of the marine sediment, producing an oxidized zone 15–20 feet thick. Brown, oxidized marine clay is recorded in highway test borings beneath tidal marshes in Scarborough, Maine, to a depth of 35 feet below high tide, implying at least that much submergence subsequent to the interval of subaerial weathering. A birch stump now submerged 13.5 feet at high tide in Blue Hill Bay, Maine, and dating from 2970 ± 140 years B.P. (Y-773) can be added to the list of previously published dates of marine submergence in coastal Maine.

A plot of radiocarbon- and pollen-dated events against a hypothetical curve of postglacial eustatic rise of sea level shows that postglacial crustal rebound lagged behind rise of sea level, then exceeded the rate of sea-level rise, and for the past 6000 years either has reversed itself or has been masked by crustal subsidence of other origin. This conclusion is based on the hypothesis that sea level has been close (±10 feet) to its present position for the past 6000 years. Other hypotheses should continue to be tested.

CALCIUM/MAGNESIUM RATIOS AS AN EXPLORATION TOOL

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The Dauntless level of Hilltop mine, Park County, Colorado has been mapped and systematically sampled at 4-foot intervals along traverses radiating from an ore body. Samples were obtained from long-hole cuttings extending from wall rock into the ore body and back into wall rock. The host rock is Leadville limestone which is known to be dolomitized in the area. The degree of dolomitization relative to the degree of mineralization has not previously been studied in detail for a given ore body.

Calcium and magnesium were determined by standard EDTA procedures involving titrations at appropriate pH levels.

Preliminary investigation suggests that the Ca/Mg ratios vary along these traverses in a manner which indicates a primary halo. There is a general decrease in the Ca/Mg ratio (increasing magnesium) toward the ore body and mineralized fractures. These changes are impossible to detect by hand-specimen observation, and acid effervescence tests are impractical to perform on cuttings because of variability of dust coating. They are equally difficult to discern by petrographic examination. EDTA methods are rapid, economical, and can be performed in the field camp.

There is sound indication that in carbonate rocks, analysis for calcium and magnesium may be used as an exploration tool.

PIGMENTS OF A FOSSIL ECHINODERM

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Fossil sea lilies of late Jurassic age from Switzerland contain an assemblage of at least six closely related hydroxyquinone pigments derived from the aromatic hydrocarbon 1.12-benzperylene. They can be separated by chromatography and fractional crystallization. Their spectra and chemical properties indicate a close genetic relationship, and it is postulated that they have been formed by a series of redox- and condensation reactions from an echinoderm pigment similar to echinochrome. The different pigments (fringelites) represent steps in the gradual reduction of the primary condensation product to the polyaromatic parent hydrocarbon, a substituted 1.12-benzperylene, which is also present in the fossil.

Discovery of this new group of fossil pigments is geochemically significant; it permits for the first time the reconstruction of a complex reaction sequence, leading in many steps from small, highly oxygenated molecules to a large aromatic hydrocarbon. From the knowledge of such transformation reactions conclusions can be drawn about the physico-chemical environment (*e.g.*, redox-potentials) in the subsurface and the possible changes in the dispersed organic matter in sediments.

FEDERAL BUREAU OF MINES RESEARCH ON WESTERN COALS AND LIGNITES

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The Denver Coal Research Laboratory of the Bureau of Mines, U. S. Department of the Interior, conducts research on many problems related to utilization of Western coals. Areas in which work has been done include fuel for power, production of blast-furnace and foundry coke, production of low-volatile carbons, coal storage, hydraulic transportation, and analysis of energy trends. The Laboratory also studies the physical and chemical properties of Western coals and co-operates in studying low-rank coals of foreign origin.

Efficient means of drying high-moisture coal and lignite have been developed by the Bureau, thus leading to opportunities for significant reduction in power costs. For the same basic reason,

carbonization has also been studied extensively, with emphasis on maximum tar yield. Such tars may ultimately provide credits against fuel cost. Techniques for improving the physical quality of coke from Western coals have been studied. Continuing work is conducted to develop, from subbituminous coal and lignite, a substitute for coke breeze in nonferrous metallurgy. Methods for safe and inexpensive storage of low-rank coal and lignite have been developed, and on-the-spot assistance has been given in storing several million tons of lignite. Hydraulic transportation of bituminous coal and lignite has been examined on pilot-plant scale, and the economics has been analyzed. Several economic studies have been made of the present and probable future competitive position of coal as a source of energy. The Laboratory has co-operated in exploring the properties and use of coals from several foreign countries, including India, Greece, the Philippines, Pakistan, Canada, and Mexico.

PROBLEMS OF A NEW GEOLOGICAL DEPARTMENT, ARLINGTON STATE COLLEGE, ARLINGTON, TEXAS

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In late May 1958, Arlington State College was raised from junior- to senior-college rank. The problems that this change created for the geology department may be interesting to others.

The department had to justify elevation to 4-year status. This was done on the bases that: (1) the enrollment of freshman-sophomore geology majors compared favorably with that in other colleges and with that in other sciences at Arlington; (2) the college is located in the densely populated Dallas-Fort Worth area of north Texas, an urban area of some 1,500,000 people; and (3) the college is located within a region in which petroleum is one of the major industries.

Curriculum organization was guided by the following factors: fundamental training in geology and in supporting sciences and mathematics; the fields of interest, training, and experience of the faculty; and the geology of the region.

Esprit de corps among majors, complicated in a commuter college such as Arlington, is encouraged by permitting access to laboratories at all times, by senior laboratory assistantships, and by other means.

Acquisition of equipment and staff was hampered by: appropriation of funds only 3 weeks before junior classes began; temporary housing; administration's uncertainty because of drastic decreases in major enrollment; and an expected but undetermined increase in nonmajor enrollment.

Future problems include accreditation of the department and college; placement of graduates in industry and graduate school; and the development of faculty research programs suited to the resources of the institution, training of students, and geology of the area.

FRACTURING IN THE PRECAMBRIAN AND ADJACENT FOUNTAIN BEDS ALONG THE MARGIN OF DENVER BASIN, WEST OF DENVER, COLORADO

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A mile-wide strip of Precambrian crystalline rocks and sedimentary formations in the foothills between Mt. Vernon Canyon and Strain Gulch (Morrison quadrangle, 1957) is in the mobile belt of the steep west margin of the Denver basin. Fracture patterns mapped east of the structural hinge indicate a break in the eastward-tilted Precambrian basement part of the wedge of Precambrian and sedimentary rocks west of Golden fault trace.

The surface of the Precambrian west of Red Rocks Park, north of Strain Gulch, and across the center of sec. 22, T. 4 S., R. 70 W., is considerably steeper in the lower 400–500 feet of east slope, west of the Fountain contact, than similar surfaces higher on Mts. Falcon and Morrison. The break-

of-slope occurs at a wide, persistent, N. to N. 20° W. shatter belt of anastomosing, quartz-veined, near-vertical, red-stained fractures. At highway level, the north wall of Bear Creek canyon entrance shows a vertical block of Fountain arkose, trapped in the fracture belt between normal east-dipping Fountain beds and faulted, deeply weathered quartz-biotite schists.

The landslide (?) of Fountain on Mt. Morrison "berm" north of Red Rocks partly covers the shatter belt below. A northwest branch of Mt. Vernon fault complex intersects exposures of quartz veins and schist breccia. The shatter belt reappears in the block of migmatite, mica schist, and pegmatite thrust against the Fountain south of the entrance of Mt. Vernon Canyon.

GEOLOGY OF CENTRAL DOMINICAN REPUBLIC

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A geologic map has been completed for an area of 3000 km² between Ciudad Trujillo and La Vega, 110 km to the northwest.

Greenschist metamorphic rocks (probably lowermost Cretaceous or pre-Cretaceous) consist of metamorphosed quartz keratophyre and basic volcanic rocks. Schistosity trends N. 40° W. at the eastern end of the Cordillera Central, but to the west along the northern flank of the range the trend changes to N. 70° W. Undated basalts and tuffs unconformably overlie the metamorphic rocks.

The oldest dated rocks are Lower Cretaceous (Middle Aptian-Middle Albian) and occur at the base of the known Cretaceous section. Cretaceous rocks are predominantly tuffs and lava flows, in large part quartz keratophyre. Deposits of wacke and limestone dominate the Maestrichtian and appear to be followed conformably by Paleocene to Middle Eocene wacke, tuff, and algal limestone. Eocene volcanism and uplift near central Dominican Republic are in marked contrast to Eocene limestone deposition in the northern and southern parts of the country.

A major period of faulting and northeastward thrusting occurred in the Late Eocene. Oligocene and younger sections are dominated by clastic sedimentary rocks, which fill deep basins north and south of the present Cordillera Central.

Plutonic igneous rocks of central Dominican Republic include peridotite, 95 km long; an augite norite batholith; stocks of pyroxene diorite, gabbro, and hornblendite; and plutons of foliated tonalite (pre-Albian?) and unfoliated tonalite (Maestrichtian-Middle Eocene).

No fault displacement exists along the landward projection of the steep scarp bordering the submarine Beata Ridge.

STABILITY RELATIONS OF PYROPE AND ALUMINOUS ENSTATITE

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The stability field of the magnesian garnet, pyrope ($Mg\ Al_2Si_3O_{12}$), has been determined in the pressure range 15–40 kb and in the temperature range 1000°–1750° C. At pressures less than those required to form pyrope, the stable subsolidus assemblage is aluminous orthoenstatite + sapphirine + sillimanite. Preliminary data indicate that these react to form pyrope along a curve given by the equation $P = 6.9 + 0.00975\ T$, where P is in kb and T is in °C. At 1505° C. and 21.6 kb this curve is intersected by the melting curve of pyrope, which has a slope of 14.1° kb. The melting of pyrope must be incongruent at the lower-pressure end of the melting curve but may become congruent at higher pressures. X-ray studies indicate that the enstatite, which crystallizes from the pyrope composition at pressures slightly less than those required to form pyrope, contains at least 14 weight per cent Al_2O_3.

These data support the view that high lithostatic pressure was required for the formation of pyrope-rich garnets in eclogites, granulites, and ultramafic rocks. Aluminous enstatites are also characteristic of granulites.

AGE RELATIONS IN EARLY TERTIARY OF EUROPE AND AMERICA AS INDICATED BY COCCOLITHOPHORIDS AND RELATED MICROFOSSILS

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The fossil remains of calcareous nannoplankton, including coccolithophorids, have been recognized for more than a century, but applications to biostratigraphy began less than 10 years ago. Literature is thus scant, although now increasing in Europe. Preliminary investigation of several thousand samples of Cretaceous to Recent age, from many parts of the world, has indicated wide geographic distribution and restricted time ranges for many species of these planktonic microfossils.

Many distinctive forms of the Maestrichtian show remarkably abrupt extinctions in the regions examined. The overlying Danian includes different forms of Tertiary aspect. The Gulf Coast Midway has an assemblage like the type Danian. Distinctive forms of the Paleocene of Europe occur in the Wilcox, including the Nanafalia and Bashi formations, although the Bashi appears transitional to lower Eocene.

Biostratigraphic zones in the Claiborne of Texas are recognizable in the middle Eocene of California and of France. The type Aragon of Mexico resembles this middle Eocene, although it is generally assigned to the lower Eocene, but a sequence, from there needs study. The recurrence in the middle Eocene of California of a foraminiferal fauna like one in the lower Eocene cannot be interpreted as reworking, from evidence of the coccolithophorids, which show two different assemblages corresponding to their sequence elsewhere.

The less common occurrence than Foraminifera, in part because of solution and recrystallization, limits the usefulness of these tiny fossils, and reworking presents difficulties in some areas but gives evidence on times of uplift and/or erosion.

GEOCHEMISTRY OF KEROGEN FROM THE SHARON SPRINGS MEMBER OF THE PIERRE SHALE

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The marine Sharon Springs member of late Cretaceous age contains as much as 8 per cent organic carbon. The member has been traced from the Canadian border to central Kansas, and from south-central South Dakota and adjacent parts of Nebraska to the Black Hills in South Dakota and Wyoming; equivalents extend into central Montana. The organic content is highest in central South Dakota where the member is thinnest.

It was not possible to isolate the kerogen mechanically from three samples, and it was finally necessary to resort to chemical decomposition of the rock; sink float was used to remove pyrite from each organic separate. Chemical and infrared analyses of the organic products showed them all to be compositionally and structurally similar to lignite or subbituminous coal. This conclusion complemented petrographic studies showing the bulk of the kerogen to occur as discrete flakes of plant material. Relative increase in hydrogen content among the kerogen isolates was attributed to increased contributions of marine organic detritus and could be correlated with greater distance from the shore line of the Pierre Sea.

The samples studied were taken from points as much as 300 miles apart, indicating distribution of terrestrial detritus over a tremendous area. Conditions permitted extensive sedimentation of

such material without a corresponding rise in the influx of clay, making the Sharon Springs more organic-rich than adjacent members of the Pierre shale. Conditions that would lead to this kind of sedimentation are difficult to reconstruct.

CHEMICAL STUDIES OF MARACAIBO BASIN CRUDE OILS

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Statistical tests of chemical analyses of crude-oil samples from the Maracaibo Basin show that two types of crude oils are present. All except 5 of 116 oils can with confidence be classified within one of two oil types.

The family of oils designated as Type I is predominantly from Miocene strata of the Bolivar coastal fields. Most of the second group, called Type II, is produced from Eocene formations. When this association is reversed—that is, when Type II is found in the Miocene or Type I in the Eocene, it appears likely that there has been intrusion of oil from one horizon to another. This occurs where Eocene and Miocene reservoirs are in contact at the Eocene unconformity.

The oils were separated by distillation, chromatography, and deasphalting and analyzed for hydrocarbon types and trace metals. Infrared, refractive-index and density data were also obtained. The results suggested that only two families of oils were present. Properties that distinguished best between the families were then used for the statistical tests.

The most outstanding difference between the two oil families is their normal paraffin contents. Type I oils contain extremely small amounts (average 1.3 per cent), while Type II oils have greater concentrations (average 13.8 per cent).

The presence of only two types of oils and the association of each type with one of the two major producing horizons does not necessarily mean that these horizons are their sources. The genesis of the two types of oils is not known.

INDEX FOR DESCRIPTION OF CHANNEL BRAIDING

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The term braided is applied to stream reaches that are divided into two or more anastomosing channels by islands or bars of alluvium. An island is visible at bankfull stage and, except in desert regions, has vegetal cover; a bar is not visible at bankfull stage and ordinarily has no vegetal cover. Braiding that changes in pattern with river stage is characterized by bars and is termed transient. Braiding that remains nearly constant in pattern is characterized by islands and is termed stabilized. The following ratio, called the braiding index, has been found satisfactory for description of channel braiding, either transient or stabilized:

$$\text{Braiding index (B.I.)} = \frac{2\ (\text{sum of lengths of islands or bars in reach})}{\text{length of reach measured midway between banks}}.$$

The braiding index is a measure of the sum of island or bar perimeters in a reach and hence of increase in bank length that results from braiding. Most islands and bars are narrow, and their perimeters are approximately twice their lengths. Lengths of islands or bars in a reach may be measured and summed in the same operation by use of a chartometer (map measure). Air photographs are much more satisfactory for measurement of braiding than are topographic maps. Distinction between braided reaches and reaches having few islands or bars is arbitrary, but a consistent distinction may be made by means of an appropriate value of the braiding index.

GEOLOGIC STRUCTURE IN THE MASCOT-JEFFERSON CITY, TENNESSEE, ZINC DISTRICT

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The zinc deposits of the Mascot-Jefferson City area, Tennessee, are confined to the Longview dolomite and overlying Kingsport limestone of Early Ordovician age. The district is near the southwest end of a lens-shaped structural block that extends about 45 miles N. 35° E. from Mascot to Mooresburg. The northwest boundary of the block is the Saltville fault. Folds and faults of the Rocky Valley fault slice form the southeast boundary. Southwest of Mascot the block is a simple southeast-dipping homocline about 3 miles wide. Northeast of Mascot, where it passes between Jefferson City and Joppa the block widens to a maximum of 15 miles and then tapers to about 4 miles near Mooresburg. In its wide part, the block is characterized structurally by the deep Strawberry Plains basin, by several broad open folds, and by minor thrust faults.

The known ore bodies occur in a belt 1–3 miles wide and about 20 miles long between Mascot and Jefferson City. The belt trends N. 75°–80° E. across the regional structural features that trend N. 35° E. The belt is defined structurally by a line of elongate domes and sharp northwest bends in the axes of folds that otherwise trend northeast. Minor faults are numerous. These structures apparently resulted from horizontal compression in a northeast-southwest direction within a structural block produced by regional northwest-directed compressive forces. Shortening caused by this folding and faulting exceeds a mile. Comparable structure is unknown in other parts of the Tennessee Valley.

COPPER MINERALIZATION IN THE CATOCTIN FORMATION, VIRGINIA

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Precambrian basalt flows, pyroclastic rocks, and interbedded sediments constitute the Catoctin formation cropping out along the crest of the Blue Ridge Mountains in Virginia and east in the Piedmont of Virginia. Copper mineralization occurs in the western belt of volcanic rocks (1) in abnormal amount in magnetite and pyroxene in some relatively fresh flows and dikes, (2) as chalcopyrite in some dikes believed to be Catoctin feeders, (3) as disseminated native copper in some flows, and (4) as disseminated native copper and in association with quartz-serpentine veins in certain epidotized basalts.

Copper concentrations are localized in flows that were initially rich in copper, where these are in contact with pre-Catoctin topographic highs. The topographic highs have impeded the lateral slippage of individual flows at their boundaries during regional deformation and metamorphism in the late Paleozoic. Intense epidotization facilitated redistribution of copper into fractured basalt. Epidotized basalts are bordered by albitized basalts. Alkali expelled during epidotization could account for the alkali increase in some portions of the formation.

SULFATE STUDIES. (I): ALUNITE-JAROSITE SOLID SOLUTION

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An alunite-jarosite solid-solution series has been synthesized at 78° C./1 atm., 105° C./1 atm. and 150° C./6.1 atm., with a 1:3 molar ratio of potassium ion to total trivalent (Fe–Al) cation, and 0.2 N H_2SO_4 as solvent to prevent hydrolysis of ferric ion. The Fe^{+++}–Al^{+++} substitution produces little effect upon c_o (17.21 Å for jarosite to 17.29 Å for alunite) but causes a continuous change in a_o

from 7.300 Å (alunite) to 6.980 Å (jarosite). The opposite results obtain from Na–K substitution in the alunite-natroalunite series and the jarosite-natrojarosite series.

Under all conditions of preparation the yield provides a higher Fe content than expected from the original trivalent ion ratio. This aids in explaining pure alunite deposits (such as the replacement types at Marysvale, Utah) that occur in latites and andesites with a silica-iron cap rock that is preserved in many places. At Marysvale, jarosite occurs as crusts on replacement-type alunite deposits where surface iron-bearing waters have caused a replacement of Al^{+++} by Fe^{+++}. It is believed, therefore, that pure alunite deposits in medium to basic igneous rocks are formed under reducing conditions since a large supply of oxygen will yield ferric ion and produce an intermediate rather than the Al^{+++} end member of the series.

CRYSTAL STRUCTURE OF A CHROMIUM CHLORITE

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The common chlorite structure, characterized by a particular talc-brucite assemblage having both random and regular layer sequences (Brindley, Oughton, and Robinson, 1950), exists over wide compositional and environmental ranges. Two other structures with different talc-brucite assemblages have been found. One such structure, so far found in five Fe- and Cr-rich specimens and five cookeites, is described here.

Purple chlorite with 9.3 per cent Cr_2O_3 from Erzincan, Turkey, has a regular layer sequence with unit-cell parameters $a = 5.34$, $b = 9.25$, $c = 14.43$A, and $\beta = 97° 05'$. The space group is $C\bar{1}$, confirmed by statistical tests on $k \neq 3n$ reflections. The structure was determined by systematically developing the 12 theoretically possible 1-layer structures and using three of these having the observed space group as models for intensity calculations. Refinement, using 250 observed reflections in successive cycles of least squares and (F_o F_c) Fourier syntheses, reduced the final reliability factor to an average value of 10 per cent for the three zones studied.

The following features of the structure are of interest.

(1) The brucite sheet is rotated by 180° relative to the common chlorite structure.

(2) The pseudo-hexagonal talc networks are distorted by 6° planar rotations of the (Si, Al) tetrahedra as a result of compression upon articulating the larger tetrahedral with the smaller octahedral sheet.

(3) The two nonequivalent tetrahedra have mean (Si, Al)–O bond lengths of 1.63 and 1.69A, suggesting ordering of Al.

(4) Cr preferentially occupies one site within the brucite sheet.

(5) The pattern of network distortion and cation ordering determines the layer sequence.

GEOLOGICAL INTERPRETATION OF LEAD-ORE ISOTOPES

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All lead ores consist of four isotopic forms (Pb204, 206, 207, 208) in varying proportions, and the last three are end products of the disintegration of uranium 238, U-235, and thorium 232. Since these are disintegrating constantly, the relative amount of the nonradiogenic form (Pb204), always small, is constantly diminishing.

From a study of the data from about 500 isotopic analyses of lead ores widely distributed through the world and the geologic column, and in the light of their geological relationships, the author concludes that the amount of Pb204 in an ordinary lead ore is an excellent index of its true age of generation. Acceptance of this thesis leads to the conclusion that the ores of lead and its associated metals (zinc, copper) are not related genetically to the igneous rocks with which they are associated

in many places but have merely been redeposited and modified by the intrusive rocks. They stem from original deposits formed by deep-seated emanations which ascended into the lower part of thick sedimentary sequences at a time when these were flat-lying and generally undergoing diagenesis.

The Mississippi Valley deposits, hitherto generally considered anomalous, are interpreted as normal unmodified representatives of the prototypes from which ores associated with igneous rocks were derived. In some cases (Broken Hill, Balmat, New York) dynamic metamorphism occurred without igneous action. Either igneous or regional metamorphism results in homogenization of the originally variable isotopes.

BRECCIA AND PEBBLE COLUMNS ASSOCIATED WITH HYDROTHERMAL ORE DEPOSITS

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Columns of rock fragments show a wide variety of form and structure and are associated with many different kinds of ore deposits. The fragments range from angular to rounded and from blocks weighing many tons to the particles that constitute a matrix of rock paste in many columns. The columns usually develop on planar structures or at structural intersections mostly in competent rocks.

Two broad divisions of mineralized rock-fragment columns are proposed: prehydrothermal and cohydrothermal. In the prehydrothermal type the spatial coincidence between the column and the ore shoots in most cases is poor because the column developed prior to and independently of mineralization, and other controls besides the configuration of the column were operative in localizing the ore. In the cohydrothermal type there is closer coincidence in time and usually in space between ore and the column because the column results from the corrosive action of the hydrothermal fluids.

Tectonic breccias, volcanic-vent fillings, intrusive igneous breccias, and filled sink and circle deposits formed by ground-water leaching of carbonate rocks, generally come under the heading of prehydrothermal structures. Breccia and shatter pipes, hydrothermal pebble dikes, and probably most porphyry copper deposits come under the heading of cohydrothermal structures.

The incidence of ore is probably higher in cohydrothermal than in prehydrothermal structures, although important ore deposits occur in both types.

GEOMETRY OF ALLUVIAL FANS IN WESTERN FRESNO COUNTY, CALIFORNIA

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Radial profiles of alluvial fans along the western border of the San Joaquin Valley in western Fresno County, California, are gently concave upward, but the slope does not decrease at a uniform rate away from the apexes. Instead, the profiles are segmented or jointed. Profiles of fans whose streams head in the foothill belt have three straight-line segments; profiles of fans whose streams head in the Diablo Range have four segments: three are straight lines, but the upper segment may be concave upward. Deposits accumulate on the upper-fan segment so that its slope approximates the slope of the valley upstream from the fan. Terraces in a drainage basin may indicate that intermittent uplift has steepened the slope of the valley floor upstream from the fan. A rapid change in the valley slope might produce a straight-line fan segment, but a gradual increase in the valley slope might be accompanied by a gradual steepening of the fan, resulting in a concave-upward fan segment. Fan-head trenching helps preserve the upper-fan segments by preventing deposition on the fan surfaces within the extent of the trenching.

Fan segmentation may be useful for deciphering part of the diastrophic history of mountain ranges, because the fan profile and the volume of material within a given fan segment reflect the erosional and diastrophic conditions within the drainage basin.

Cross-fan profiles parallel to the mountain front show that the convex upward curvature of the fans decreases downslope.

STRUCTURAL GEOLOGY OF THE MEDANO PEAK AREA, SANGRE DE CRISTO RANGE, COLORADO

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The Medano Peak area is part of the Sangre de Cristo Range, which is one of the most intensely deformed ranges of the Rocky Mountains of Colorado. Most of the structural features of the area are of Laramide origin. The dominant feature is eastward thrusting. Laramide structures include a low-angle thrust that involves the Precambrian complex, several high-angle thrusts (used after the manner of Hills, 1899, p. 1) that cut the Sangre de Cristo formation along the east flank of the range, a probable fenster of the Sangre de Cristo formation near Mosca Creek on the west side of the range, and a probable klippe of Precambrian rock near Muddy and Bruff creeks.

Principal conclusions are as follows: (1) The Precambrian complex has been thrust eastward, at a low angle, over the Sangre de Cristo formation. (2) The high-angle faults, except one, that cut the Sangre de Cristo formation along the east flank of the range are high-angle thrust or reverse faults that probably decrease in dip with depth to the west and merge along one or more nearly flat zones of thrusting. (3) The orientation of Laramide structures in the area was possibly determined by the couple action of the active westward force in northern Colorado and an active eastward force in southern Colorado.

COMPOSITION OF THE MAGMATIC VAPOR PHASE

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The composition of the water-rich vapor phase coexisting with silicate melts of different compositions at pressures from 2 to 9 kilobars and temperatures from 550° to 1000° C. has been determined by chemical analysis of quenched condensates. The samples for analysis were obtained in recently developed pressure vessels that have sample capacities of 30 cc or more.

The aqueous phase coexisting with albite crystals in the pressure range investigated has the composition of albite plus water, whereas the aqueous phase coexisting with liquid, initially of albite composition, contains considerably less SiO_2 but nearly the same Na_2O/Al_2O_3 ratio as albite plus water. The aqueous phase coexisting with liquid, initially of nepheline composition, also contains less SiO_2 than nepheline plus water, but the Na_2O/Al_2O_3 ratio is slightly higher than in nepheline.

Preliminary results indicate that the composition of the aqueous phase coexisting with condensed phases initially in the system $KAlSi_3O_8$–$NaAlSi_3O_8$–SiO_2–H_2O is dependent upon the nature and bulk composition of these condensed phases, as well as upon pressure and temperature. Generally, however, the aqueous phase coexisting with liquids that approach granites and granite pegmatites in composition has higher Na_2O/K_2O and lower $Al_2O_3/Na_2O + K_2O + SiO_2$ ratios than the coexisting liquids.

These experimentally determined relationships, combined with the measured total solubilities of the condensed phases in the vapor and of water in the liquid phase, provide a quantitative basis for understanding the processes of pegmatite formation, contact metasomatism, and hydrothermal alteration.

REFINEMENT OF THE CRYSTAL STRUCTURE OF ANDALUSITE

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The crystal structure of andalusite has been refined in conjunction with a detailed study of the relationships between the structures and stability ranges of the aluminum silicate minerals. X-ray diffraction intensities were measured with a single-crystal counter diffractometer, using a crystal of andalusite from Minas Gerais, Brazil. The crystal is a rectangular prism; hence a detailed absorption correction was calculated for this particular shape.

The least-squares refinement, which was carried out on the IBM-704 computer at the M.I.T. Computation Center, was initiated using the atomic co-ordinates given by Taylor (Zeit. Krist., 1929, v. 71, p. 205). Based on 350 *hkl* reflections, these original co-ordinates yielded a disagreement factor, *R*, of 43.9 per cent. After nine cycles of refinement the final unweighted *R* is 5.7 per cent, and the weighted *R* is 3.6 per cent.

Taylor's original structure was found to be fundamentally correct. Chains of aluminum octahedra sharing two edges lie parallel to the c axis. These octahedra depart appreciably from ideality; two of the aluminum-oxygen bond distances are 1.83 Å, two are 1.89 Å, and the two aluminum–oxygen distances normal to the c axis are 2.09 Å. These octahedral chains are linked together by alternating silicon tetrahedra and five-fold co-ordinated aluminum groups. The silicon–oxygen bond distances are 1.64 Å, 1.62 Å, 1.63 Å, and 1.63 Å. The aluminum–oxygen bond distances in the five-fold co-ordination group are 1.82 Å, 1.82 Å, 1.82 Å, 1.84 Å, and 1.88 Å. A very short bond distance of 2.25 Å exists between two adjoining oxygens in this five-fold co-ordination group.

HYDROGEOLOGY OF LIMESTONE TERRANE IN SOUTHWESTERN GEORGIA

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The Dougherty plain of southwestern Georgia is a region of karst topography, underlain by the Ocala limestone of late Eocene age, one of the components of the principal artesian aquifer of coastal Georgia and Florida. The plain is drained by the Flint River and its tributaries, which have cut downward through 10 to 70 feet of residuum into the uneven top of the limestone. Interstream areas are characterized by prominent sinkholes and low, broad areas of interior drainage.

Water is recharged to the limestone in the interstream areas; it is discharged from hundreds of springs in the exposed limestone along the sides and bottoms of streams.

The water table fluctuates seasonally with precipitation and evapotranspiration in both the residuum and the limestone, but the fluctuations in the limestone are smaller. Although the two are connected hydraulically, the residuum acts somewhat as a confining layer.

The contact of the limestone and residuum is sharp but uneven. Limestone pinnacles protrude upward into the residuum at least 20 feet. Solution cavities in the upper part of the limestone are as much as 300 feet by 100 feet by 80 feet, have fluted sides, contain dripstone, and have bottoms covered with silt. In some of the shallower caverns, small streams flow in well-defined channels on the bottom.

Pollution of ground-water supplies has been a problem for many years because of the thin residuum, sinkholes, and rapidity of ground-water movement through the caverns. After periods of heavy precipitation, springs commonly disgorge large quantities of sand, mud, and dead vegetation.

REVISIONS IN THE MICROLITHOTYPE CONCEPT OF COAL*

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Microlithotypes have been defined previously as microscopically identifiable typical associations of macerals with a provisional minimum band width of 50 microns. The commonly recognized microlithotypes are distinguished, one from another, on the basis of arbitrarily fixed percentages of the maceral groups, vitrinite, exinite, and inertinite. The concept as applied in this paper departs from the above in the following manner:

(1) No pre-established delimitations are employed. A coal seam is examined in terms of its simplest constituent lenses. The maceral composition of these lenses is determined, and these data are then examined in such a manner that the natural maceral associations appear as discrete populations. These populations are considered microlithotypes.

(2) Eight basic macerals or maceral groups are identified and quantitatively determined in the microscopy of the various lenses, and each is given equal value in the establishment of the microlithotype populations.

Selected dull bands and adjacent bright layers from the Harbour coal seam, Sydney Coalfield, Nova Scotia, were used as the subject material of this study. Two orders of microlithotypes are distinguished, simple types and complex types. The former represent distinctive aggregates of maceral particles occurring as compositional populations and forming the fundamental lenses of coal seams. The latter represent natural assemblies of the simple types. Sixty-two simple and nine complex types have been described.

ROTATION PROPERTIES OF CERTAIN ANISOTROPIC ORE MINERALS

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Over a period of 5 years, the authors have measured the rotation properties of 82 anisotropic ore minerals at 470, 520, 546, 589, 620, and 650 mμ in air, and 589 mμ in oil. Values of the rotation angles for the various minerals range from sensibly 0° to 23.2°. Phase differences of most of the minerals are positive. The minerals studied show four patterns of dispersion of the rotation angle (A_r) with wave length and several patterns of dispersion of the phase difference 2θ.

The data obtained lead to the following conclusions: (1) The range of rotation angles of anisotropic ore minerals in air is very broad relative to the accuracy of measurement, which is commonly ±0.1° to ±0.2°; measurement of rotation angles therefore can assist substantially in mineral identification. (2) Dispersion phenomena are a second aid to identification. (3) The sign of the phase difference for a mineral is easily determined and is a supplemental aid to identification. (4) The color phenomena of polarization figures are in some cases distinctive, hence useful in identification of certain minerals. (5) For most of the minerals studied, surface films produced by polishing do not affect the reliability of rotation angles for identification of minerals in polished surfaces.

The use of rotation properties greatly extends the range of minerals that can be identified rapidly under the microscope without recourse to special supplementary techniques.

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TEACHING ALPINE STRUCTURAL GEOLOGY IN FRENCH

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In spite of the required reading and translation examinations for the Ph.D. most geology students have not been exposed to enough spoken French to be able to understand a foreign geologist or participate in a discussion in an international congress.

The graduate course in Alpine Tectonics given in the fall semester of 1959–1960 at the University of Illinois, designed to provide a specialized training in structural geology, was used also to give experience in discussing geology in French. The class consisted of 10 graduate students who had already passed the Ph.D. French reading examination. No auditors were admitted.

The course relied strongly on discussion of structural cross sections drawn on the blackboard, on analysis of geological maps, and on numerous slides. At the beginning the lecturing was in two languages. This method of teaching was carried on during 4 weeks until most of the technical vocabulary had been assimilated. Gradually the English was reduced and finally dropped almost completely.

Most of the students took their notes in English with side notes in French, or conversely when their knowledge of French was sufficient. Each student read widely in the French literature of the Alps and presented written reports as well as oral discussions. The final examination tested their knowledge of Alpine Geology and their ability to analyze and discuss contrasting hypotheses which were presented in a lengthy French essay they had not seen previously.

BASIN MORPHOLOGY AND SEDIMENT DISTRIBUTION OF AN ORIENTED ARCTIC LAKE

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Study of an artificially drained lake basin provides the basis for an interpretation of lake orientation on the Alaskan Arctic Coastal Plain near Point Barrow.

Typical of others near Point Barrow, this basin is approximately 5500 feet long and half as wide, with a maximum depth in a flat central basin of 5 feet. The central basin extends to the ends of the lake but is bounded on the sides by wave-cut littoral shelves. The shelf on the west side is made prominent by a bordering high bank, while that on the east is bordered by a low bank and is mantled with allocthonous peat, which makes it less conspicuous. Median grain size ranges from .15 mm on the west shelf and .02 mm on the east shelf to .01 mm in the central basin. Organic-matter content ranges from 2 and 27 to 35 per cent; and depth to permafrost from 30 and 18 inches to 13 inches, respectively. The basin morphology and sediment distribution reflect the influence of alternate easterly and westerly winds, which produced wave attack on the sides and currents around the ends.

Permafrost moisture content decreases from about 70 per cent in the upper 8 feet to 25 per cent below this depth, limiting the depth of thaw basins. The result is a limited wave velocity and, therefor, a tendency toward equilibrium profiles and restriction of basin expansion in width. Orientation may be thus effected.

MORPHOLOGY AND AFFINITIES OF *EOCRINUS*, AN ARCHETYPE OF THE ECHINODERMATA

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Original types of *Eocystites*?? *longidactylus* Walcott, 1886 (type of *Eocrinus* Jaekel), Lower? and Middle Cambrian of Nevada, and new material from the Middle Cambrian of Alberta (n.sp.)

reveal much about these oldest echinoderms. The nearly intact Canadian specimen preserves the stele, a bluntly tapering, sterete, polyplacate tail (rather than the presumed stem). The stele and theca intergrade. The habitus was eleutherozoic.

The theca is covered by discrete, contiguous, polygonal, nonpore-bearing, crystalline calcite plates, which show no labyrinthine canals. The plates are not regularly arranged. Plate size is bimodal. The body was highly flexible.

Large sutural pores, shared by contiguous plates, incise plate outlines into lobate rosettes. Many of the sutural pores extend normal to the suture, recalling incipient epispires (Hudson, 1915), hence "protoepispires". The result recalls the holothuroid and larval crinoid skeletons.

Eleven long, biserial brachioles (Alberta specimen), sharply delimited from the theca, consist of subequal, regularly alternating brachial pieces. Each brachial piece bears two pentagonal, interdigitating cover plates which, in life, gabled the deep ambulacral groove. A lumen perforates each arm. The anus is not identified; evidence for a tegmen is obscure.

The Eocrinoidea are redefined. An argument is developed that the taxon be restricted to archaic forms with intersutural pores, biserial, nonpinnulate brachioles and eleutherozoic tails. Eocrinoid affinities to the holothuroids are reassessed, and taxonomic validity of the Pelmatozoa and Eleutherozoa re-examined. The first reappraisal is positive; the second, negative.

U-Pb AGES IN THE LITTLE BELT MOUNTAINS, MONTANA

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Isotopic uranium-lead age determinations have been performed on four zircon and two monazite samples from the Archean migmatite gneisses of the Little Belt Mountains, Montana. The samples were from five different exposures along a 5-mile traverse which cut across the strike of the foliation of the gneisses.

The two monazite samples yielded concordant results at 1920 ± 30 m.y. The four zircon samples were all highly discordant and had Pb^{207}/Pb^{206} ages of 1650, 1920, 1940, and 2380 m.y.

Potassium-argon age determinations on a number of biotite and hornblende samples from these same rocks yielded results ranging from 1500 to 1780 m.y.

The following conclusions were reached:

(1) On the basis of the concordant monazites, it is concluded that the area experienced a metamorphism 1920 ± 30 m.y. ago.

(2) On the basis of the potassium-argon results, it is concluded that the last substantial metamorphism in this area occurred prior to 1800 m.y. ago.

(3) In the light of the first two conclusions, analysis of the discordant zircon results leads to the conclusion that the area underwent a previous (perhaps the initial) metamorphism 2700 m.y. ago, and the discordancy of the zircons is primarily due to lead loss by diffusion.

GEOCHEMICAL IDENTITY OF PRODUCED CRUDE OILS

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Knowledge of whether crude oils produced from various wells in an oil field are of common origin despite differences in their properties is important to operators and refiners alike and is an aid to greater conservation. Routine examinations of such oils, although used in conjunction with geologi-

cal data, commonly are not enough to solve the problem. Comprehensive studies of trace constituents are a valuable addition to previous methods that have been used.

Samples of fluids produced from several wells in a small Mid-continent oil field were separated with an ultracentrifuge into brine and oil by the Bureau of Mines. The oil samples were then subjected to routine examinations, including distillation by the Bureau of Mines routine method, and by determination of sulfur, nitrogen, specific gravity, and viscosity. In addition, the contents of the trace constituents—porphyrins, nickel, and vanadium—were determined.

Correlations of these data indicate that the several samples were of common origin and that differences in their properties are attributed to the varying loss of volatile materials through fractured zones in the reservoir. The general application of the described geochemical methods should be helpful in determining more exactly the source of crude oils.

EXPERIMENTAL DEFORMATION OF QUARTZ SINGLE CRYSTALS AT 27–30 kb CONFINING PRESSURE AND 24° C.

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Crystallographically oriented right circular cylinders of quartz were cut from optical quality single crystals, jacketed in thin-wall copper tubing and deformed by uniaxial compression in a supported tungsten carbide cylinder using bismuth as the pressure medium. The apparatus was that of G. C. Kennedy. Failure occurred in every test by sudden rupture of the cylinders; cohesion was usually retained. The strengths at rupture ranged from 41 to 47 kb, depending on crystallographic orientation.

The crystals were etched to distinguish the positive- and negative-unit rhombohedra, and duplicate cylinders were cored in eight directions in a zone normal to an a axis. Oriented thin sections were cut from the deformed cylinders and examined on a petrographic microscope with a universal stage.

Four types of planar structures, all of which show crystallographic control of their orientation, are visible in thin section: (1) faults showing evident displacements, (2) sets of parallel feather fractures close to the faults, (3) other regular sets of planar fractures, (4) curved fracture surfaces.

Several sets of faults, oriented parallel to crystallographic planes of low indices, are present in most specimens. Displacement along these was the principal mechanism of deformation. They are commonly developed parallel to the base {0001}, the unit rhombohedra z $\{01\bar{1}1\}$ and r $\{10\bar{1}1\}$, and rarely to the prisms m $\{10\bar{1}0\}$ and a $\{11\bar{2}0\}$. A thin layer of isotropic material is present along the faults. The quartz in a narrow zone close to some of the faults is reoriented; this may be a result of plastic flow or rotation of submicroscopic blocks bounded by fractures.

EARLY PALEOZOIC SEDIMENTATION IN CENTRAL IDAHO

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Ordovician and Silurian strata in the Lemhi and Lost River ranges are dolomite and quartzite on the order of 2000 feet thick. To the west in the Hailey quadrangle is more than 12,000 feet of correlative strata of graptolite shale with interbedded siltstone and sandstone. A shaly limestone, shale, and sandstone assemblage totalling about 9000 feet is recognized in the Bayhorse quadrangle. Newly measured sections imply north-south depositional trends that parallel tight folds internal to the northwest-trending fault-block ranges.

The carbonate-quartzite assemblage is interpreted as a thickened cratonic suite deposited near

the craton margin. In contrast, the graptolite shales are considered to represent a close approach to eugeosynclinal conditions. The shaly limestone, with interbedded clastic rocks, appears to be transitional between these cratonic and eugeosynclinal extremes.

The transitional assemblage is not present everywhere, and the graptolite shales seem to have been thrust eastward onto the carbonate-quartzite facies so that the shales lie on strike with transitional rocks. Such displacements of facies belts are similar to those encountered in Nevada and may represent a northern extension of the Antler or younger orogenic belts across the Snake River downwarp.

STRUCTURE AND NATURE OF THE WALL OF *STREBLUS BECCARII* (LINNÉ)*

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Examination of topotypes of this species reveals a peculiar kind of chamber structure and contrasting types of wall structure in different parts of a single specimen. The final chamber lacks an axial wall and is open at its base on the ventral side. The "aperture," therefore, is a continuous opening extending along the base of the apertural face and the umbonal area. All the earlier chambers are separated from the umbonal area by axial walls, and the apertures are limited to low openings at the bases of the apertural faces. Contrary to earlier reports, there are no tooth plates. In all but the last chamber there is a lip beneath the aperture which, in thin sections, looks like a remnant tooth plate. Actually, this is an extension of the axial wall of the preceding chamber and cannot be considered a structure homologous to a tooth plate. The axial wall of the new chamber is attached at the bottom of the lip.

The septa are single, except near the outer margins where the wall of the new chamber is attached. There is a progressive thinning of the wall during growth, but there are no laminations. The wall is porous and has a fine, radially arranged fibrous structure. In contrast, the septa are imperforate and are made of small, interlocking grains that are irregular in shape. The umbo is also imperforate and is composed of coarse, interlocking crystals.

CRYSTAL STRUCTURE OF REEDMERGNERITE, THE BORON ANALOGUE OF ALBITE

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As part of a continuing study of borates and silicates, the crystal structure of reedmergnerite, $NaBSi_3O_8$ (isostructural with albite, $NaAlSi_3O_8$), has been investigated. Reedmergnerite was first described from an occurrence in the Green River formation, near Duchesne, Duchesne County, Utah, U. S. A. (Milton, Chao, and Axelrod, 1960, Am. Mineral., v. 45, p. 188). In the albite orientation, the crystallographic data for reedmergnerite are: triclinic $C\bar{1}$, $a = 7.82_1$, $b = 12.37$, $c = 6.79_5$ Å (all $\pm 0.3\%$), $\alpha = 93° 25'$, $\beta = 116° 09'$, $\gamma = 91° 45'$ (all $\pm 5'$); density (g.cm.$^{-3}$) obs. 2.69, calc. 2.78 for cell contents $4[NaBSi_3O_8]$.

Initial atomic parameters were derived from the low albite structure (Ferguson, Traill, and Taylor, 1958, Acta Cryst., v. 11, p. 331) and refined by Fourier techniques. Least-squares analysis of three-dimensional data was then carried out on a Burroughs 220 digital computer, using a U.S. Geological Survey program employing the complete matrix associated with the normal equations. In the later stages of the analysis individual isotropic temperature factors were refined. The refinement shows that, among the four crystallographic sites [$Si_1(O)$, $Si_1(m)$, $Si_2(O)$, $Si_2(m)$] available for substitution of boron into the albite structure, the boron in reedmergnerite is located chiefly in site $Si_1(O)$. This

* Approved for publication by the Secretary, Smithsonian Institution

site in low albite is occupied largely by aluminum, according to the structural study of Ferguson *et al.* At the present stage of refinement, the average of the individual isotropic temperature factors for the atoms of reedmergnerite is 0.6Å²; the isotropic temperature factor of the Na atom has exactly this value.

ARSENOPYRITE As:S RATIO AS A POSSIBLE GEOBAROMETER

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Available geothermometry techniques frequently enable evaluation of deposition temperatures. Quantitative determination of confining pressures would greatly improve our understanding of the physical conditions of ore deposition. Investigations in the Fe-As-S system indicate that arsenopyrite may serve as a geobarometer where the deposition temperature can be estimated by an independent means.

In the FeS_2–$FeAs_2$ pseudobinary T-X section at <1 bar, the arsenopyrite stability field slopes (in relation to FeAsS) from arsenic-rich compositions above approximately 500° C. to sulfur-rich compositions below. Changes in the shape and position of this unusual stability field were investigated: (1) under confining pressures of 1000 and 2000 bars, and (2) in the presence of cobalt and antimony —the two minor elements most commonly found in natural arsenopyrites.

X-ray determination of the d_{131} crystallographic value was employed for rapid, precise measurement of the arsenopyrite As:S ratio. At <1 bar arsenopyrites on the sulfur-rich solvus at 500° and 600° C. have d_{131} values of 1.6340 and 1.6353 Å, while at 2000 bars the respective values are 1.6315 and 1.6327 Å. The values are unchanged by 1 per cent Sb but increase 0.0007 Å with 1.25 per cent Co in the arsenopyrite.

In application, the arsenopyrite must (1) have been deposited in a sulfur-rich environment (judged from mineralogy), and (2) contain no cobalt (1.25 per cent Co will lower the estimated pressure about 500 bars). If formation temperature is estimated independently within ±40° C., perhaps employing the sphalerite geothermometer (Kullerud, 1953), and d_{131} is measured to ±0.0003 Å, the confining pressure of arsenopyrite deposition is given within ±400 bars, from the sulfur-rich P-T-X surface of the arsenopyrite stability field.

STRUCTURAL IMPLICATIONS OF A PALEOMAGNETIC INVESTIGATION, NORTHERN TOBACCO ROOT MOUNTAINS, MONTANA

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Distributions of directions of remanent magnetization from most measurable geologic bodies in the vicinity of the Northern Tobacco Root Mountains, Madison County, Montana, are interpreted on the basis of structure, mineralogy, and geologic history as follows:

(1) Most samples retain a pre-Laramide magnetization. Detailed analysis reveals that the mean direction of magnetization is a sensitive indicator of relative structural movement, unless a critical pressure was reached during deformation. Increased displacement and strain result in a progressive scatter in the directions of magnetization.

(2) Precambrian Pony amphibolites show magnetizations that are parallel to planes of schistosity despite later deformation.

(3) Precambrian Belt siltstones are magnetic because of hydrothermally deposited hematite. The time of mineralization-magnetization is bracketed as Late Cretaceous.

(4) The Butte batholith and associated stocks show a Late Cretaceous pole position and no tilting following emplacement; however, one related quartz monzonite sill in tilted sedimentary rocks must have been intruded prior to deformation.

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(5) Pre-folding magnetization is indicated by andesite and diorite intrusions in folded sedimentary rocks.

(6) Three pyroclastic beds near the base of the Elkhorn Mountains volcanics show a sequence of normal-reversed-normal magnetizations. Random directions of magnetizations from the pyroclastic fragments of an Elkhorn Mountains agglomerate demonstrate magnetic stability for this rock type.

COASTAL SAND DUNES OF MONTEREY BAY, CALIFORNIA

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The dunes bordering Monterey Bay are almost entirely stabilized. They are at present undergoing wave erosion.

Two ages are clearly recognizable in the most extensive area, south of the Salinas River. The older is represented by a wide expanse of dunes, much subdued although in part retaining characteristic dune topography, extending inland several km, with average thickness of at least 30 m. There is a soil profile varying in development. The younger dunes constitute a narrow marginal belt surmounting the wave-cut bluff, in which appears in section the soil layer of the older dunes. In the younger belt the characteristic form is the parabola. These dunes are for the most part stabilized; here and there rejuvenation is occurring. There is no soil profile.

The principal sources of sand for the enormous accumulation at the south end of the bay are the Pajaro and Salinas rivers. With each eustatic rise of sea level during the Pleistocene, alluvium was stored in the valleys of these rivers; with each eustatic fall it was carried into the bay, drifted southward with the longshore current, became trapped by the projecting Monterey Peninsula, and was carried inland by the northwest wind. The older dune sheet thus represents accumulation during repeated eustatic cycles. The youthful marginal belt was formed during the latest eustatic rise, roughly equivalent to the Flandrian transgression. Similar episodes were doubtless associated with previous transgressions.

STRUCTURAL FEATURES OF THE BEATTY AREA, NEVADA

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Paleozoic rocks in Bare Mountain (southeast of Beatty) and in the southern end of the Grapevine Mountains (southwest of Beatty) have been intensely deformed by thrust faults, strike-slip faults, and folding. In Bare Mountain, north-south trending right-lateral faults are prominent; thrust plates, in part imbricated, moved first toward the southwest and later toward the southeast. In the southern Grapevine Mountains, a thrust plate moved toward the northeast, and underlying shale was folded with axes perpendicular to this direction.

The intense deformation of the Paleozoic rocks probably occurred in the Mesozoic and may be related to the major deformation of the Las Vegas Valley shear zone that projects northwestward toward the valley east of Bare Mountain. During a long erosion period following this deformation monolithologic breccia masses of carbonate rocks formed by landslides, which moved eastward off the Grapevine Mountains thrust plate.

Tertiary volcanic rocks consisting of tuffs, welded tuffs, and lava flows northeast and northwest of Beatty have been intricately fractured and tilted. In the western part of the area the Tertiary rocks

form a broad dome, ringed by rhyolitic intrusive rocks and flows, that probably represents a caldera caused by the emplacement and later withdrawal of magma from an underlying chamber.

Basin-Range normal faults developed in the late Cenozoic and have determined in large part the present physiographic patterns of the valleys and mountains.

SLUMGULLION EARTHFLOW AND EARTH SLIDE NEAR LAKE CITY, COLORADO

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Slumgullion earthflow descends 2600 feet in 4½ miles from the Cannibal Plateau margin to Lake Fork valley, which it dams to form Lake San Cristobal. Intermittent observations since June 1938 reveal that the lower, downstream one-third is stable but that the upper two-thirds is being overridden by an active earth slide from the same cirquelike source area. Yearly movement ranges from 12 feet in the central part to a foot at the toe. Uniform velocity from side to side indicates essentially unit movement on a bounding slip surface rather than viscous flowage. Lobes of the stable part occupying depressions, however, suggest flowage; other conspicuous topographic features are high-marginal ridges, superposition of marginal streams onto bedrock spurs to form waterfalls, and blocked tributary valleys. Wood incorporated in the stable flow has a radiocarbon age of 700 ± 200 years (W-822); the oldest tree found on the active part is 330 years old.

The Slumgullion source material is hydrothermally altered Tertiary latite flows and breccias on the northeastern margin of the Lake City caldera. A series of progressively more altered samples of these rocks shows relative increase of silica, soluble calcium, and soluble sulfate, and a decrease in total iron and Na_2O, accompanied by a decrease in pH from 7.2 to 3.4. Alteration apparently began with pyritization, followed by conversion of silicates to clay and oxidation of the pyrite. The end product here is chiefly montmorillonite with minor amounts of gypsum, feldspar, quartz, and biotite. Kaolinite was not detected by X-ray analysis.

DEFORMATION OF BONNEVILLE SHORE LINES

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G. K. Gilbert (1890) showed that shore lines of ancient Lake Bonneville exhibit a pattern of concentric uplift that he ascribed to isostatic rebound after unloading. Because Gilbert depended partly on barometric leveling, many writers discount this conclusion and use a nominal altitude of 5135 feet for any Bonneville shore line.

Many new shore-line elevations have been obtained from recent topographic maps and aerial photographs, particularly around the western edge of the Bonneville basin where Gilbert's maps were incomplete. They show:

(1) Regional tilting in the north-south direction is small; shore lines at the end of long shallow arms in southern Utah stand at 5100 to 5120 feet altitude compared with Gilbert's 5114 feet at the Red Rock Pass outlet in southern Idaho. Tilt in an east-west direction is obscured by isostatic uplift and faulting but does not appear greater.

(2) Confirmation of Gilbert's pattern of isostatic rebound. Elevations of 5300 feet for the Bonneville shore line in the Hogup Mountains indicate maximum uplift near 200 feet. This is about 70 per cent of the theoretical maximum based on the average water depth in a circle of 25-mile radius (900 feet) and assumed subcrustal density of 3.2.

Because the traditional 5135-foot level is used as a reference plane, many writers conclude that movement on the Wasatch fault was up on the east relative to sea level. Allowing for isostatic uplift, however, the shore-line elevation at the fault would be nearer 5200 feet, indicating that movement was partly, or perhaps mostly, down on the west.

MINERAL FACIES IN METAMORPHIC ROCKS FROM CENTRAL KOOTENAY LAKE, BRITISH COLUMBIA

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Heterogeneous, medium- to high-grade, regionally metamorphosed rocks of Precambrian through Triassic age are exposed in a narrow belt on central Kootenay Lake, facilitating direct comparison of mineral facies for pelitic, calcareous, and mafic rocks.

A complete graphical analysis of mineral facies in pelitic schists using the AFM projection in the system SiO_2–Al_2O_3–MgO–FeO–K_2O–H_2O is hampered by an insufficient range of bulk compositions that yield a limited number of assemblages in the lower metamorphic grades. In the staurolite zone and above, however, the sequence of mineral facies can be demonstrated. Chemically analyzed, coexisting garnet, staurolite, and biotite from discontinuities in facies in the staurolite and sillimanite zones indicate that these phases concentrate FeO over MgO in this order: garnet, staurolite, biotite. Garnet, kyanite, sillimanite, staurolite, biotite, and chlorite coexist in one specimen for a total of six phases (excluding quartz and muscovite) in the system considered. Although strict application of the phase rule postulates invariant equilibrium, this is believed unlikely for the following reasons: (1) metastability of Al silicates, (2) varying bulk composition of sample, (3) presence of extra components (garnet has 5.5 per cent CaO), (4) chlorite possibly a retrograde product.

The abundant calc-silicate assemblages of the area can be treated by projections in the system SiO_2–Al_2O_3–CaO–FeO–MgO–H_2O–CO_2 using epidote (stable into the sillimanite zone) or calcite as projection points. Analyzed coexisting garnet, idocrase, and diopside show that garnet concentrates FeO over idocrase, and idocrase over diopside.

DIFFERENTIATION IN THE RIM ROCK DIKE SWARM, TRANS-PECOS TEXAS

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About 100 dikes crop out between the Rim Rock escarpment and the Rio Grande at the western margin of the Davis Mountains lava field. The oldest dikes strike northwest and are composed chiefly of basalt and trachybasalt. They are intersected by north-trending dikes which range in composition from trachybasalt to mafic analcime phonolite and lamprophyre. Several lamprophyric dikes contain extremely large crystals of biotite, pyroxene, titaniferous amphibole, plagioclase, and anorthoclase. Most of the dikes are vesicular, and at least one has a remarkable core of giant feldspar phenocrysts which appear to have been concentrated and swept upward by streaming gases. Many dikes have a peculiar pellet structure in which small marblelike masses of trachybasalt grade outward into interstitial lamprophyre consisting of olivine, other mafic minerals, alkali feldspar, and analcime.

Northwest- and north-trending sets of small normal faults parallel the dikes. The dominant normal fault of the region, the Rim Rock fault, transects the dikes and smaller faults. The Rim Rock fault served as a locus for the youngest outbreak of basalt, which is similar to that in some of the earliest dikes.

The history of the dike swarm is interpreted as follows: (1) emplacement of underlying pluton of alkaline gabbro; (2) development of northwest dikes and faults; (3) shift of stress pattern and development of north dikes and faults; (4) solidification of the pluton that fed the dikes; (5) major displacement on the Rim Rock fault accompanied by generation of new basaltic magma.

HIGH TEMPERATURE–PRESSURE STUDIES OF WOOD

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Four different woods, *Araucaria cunninghamii* Sweet, *Picea glauca* (Moench) Voss, *Guaicum officinale* L., and *Taxodium distichum* (L.) Rich, have been subjected to various temperatures and pressures in a cold-seal pressure vessel (Roy and Tuttle, 1956). Temperatures ranging between 60° C. and 472° C. were employed, with pressures ranging from atmospheric to 15,000 p.s.i. and time ranging from 2 hours to several days.

A Bridgman-type uniaxial pressure apparatus (Dachille and Roy, 1959) was used to subject samples of *Taxodium sp.* to uniaxial pressures of up to 100,000 p.s.i. for periods up to several days. The temperatures employed ranged between room temperature and 450° C.

Materials have been produced that, in thin section, are optically indistinguishable from naturally occurring coal macerals. The bulk of the translucent residue is presumed to be vitrinitic and is derived almost exclusively from the cell walls of the subject materials. It was observed that: (1) temperatures over 400° C. generally produce opaque residues, (2) the outer rims of the pit borders (position of the annulus in certain conifers) are accentuated by a lower degree of translucency, (3) material filling cell lumens and that between walls of adjoining cells becomes darker than the cell-wall matter under identical conditions, and (4) two processes are acting, and these are referred to as vitrinization and micrinization.

PLACE OF FOREIGN LANGUAGES IN GRADUATE STUDY OF GEOLOGY

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Intellectuality is no substitute for intelligence, but, unless graduate study is at least intellectual, it is not scholarly. A unilingual intellectual is a lame scholar. In geology foreign language is also an indispensable tool. Language study should begin before high school, and universities can encourage early study by means of entrance requirements. The capstone of supervised study is the graduate school, and the most effective mentor is the departmental graduate faculty. Continual use by graduate student and graduate professor gives meaning to the required preliminary study.

PLASTIC FLOW IN KANSAS SALT MINES AT LYONS AND HUTCHINSON

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Removal of salt at depths of 650 feet at Hutchinson, Kansas, and 1000 feet at Lyons, Kansas, has initiated plastic flowage in pillars in these room and pillar mines. In both mines, spreading of the pillars has been recorded, and in the Lyons mine flattening of the pillars has also been measured. At Lyons a shale parting below the salt floor has acted as a lubricating layer with the spreading pillars applying a lateral force to the salt layer above the shale. This has resulted in buckling and fracturing of the salt floor. Flowage continues indefinitely but at a decreasing rate.

GRAVITY PROFILES ACROSS THE SANGRE DE CRISTO RANGE, COLORADO

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Several gravity profiles have been established across the Sangre de Cristo Range to obtain the regional setting for a geophysical study of the Huerfano basin. The variation in Bouguer anomalies

across the range and into the San Luis Valley is of the order of 100 milligals. While many ambiguities are inherent in the interpretation of gravity data alone, the magnitude of these anomalies indicates a great thickness of sedimentary material on the west side of a fault between the San Luis Valley and the Sangre de Cristo Range. There are also indications of step faulting under the eastern part of the San Luis Valley in the vicinity of the Great Sand Dunes National Monument.

COMPARISON OF TWO METHODS FOR DETERMINING PERCENTAGE OF DOLOMITE IN A CARBONATE ROCK

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Previous research has shown that carbonate rocks with poor service records as concrete aggregates characteristically exhibit a low calcium to magnesium ratio (high dolomite content). The classification of potentially deleterious aggregates and evaluation of mineralogical changes resulting from aggregate-cement reactions necessitates an accurate procedure for determining the calcite to dolomite ratio in a carbonate rock, which led to a comparison of two different methods.

The percentage of dolomite in several specimens was obtained by the X-ray diffraction method of Tennant and Berger, which consists of measuring the strongest intensity diffraction line for calcite and dolomite, respectively, and relating their intensity ratio to a standard curve.

The same specimens were examined according to the Hiltrop and Lemish method, which requires solution of the following simultaneous equations for moles of calcite, N_c, and moles of dolomite, N_d.

$$Ca_s^{++} = (1 - x)N_c + (1 - y)N_d,$$

$$Mg_s^{++} = xN_c + yN_d.$$

The variables Ca_s^{++} and Mg_s^{++} (number of moles of calcium and magnesium in the sample), were determined by versenate titration. The variables x and y (amount of magnesium in solid solution in calcite and dolomite, respectively) were determined from Goldsmith and Graf's relationship of lattice constants to the magnesium content of calcite and dolomite.

The results were comparable, within a few per cent, for most specimens. The Hiltrop and Lemish method gave results consistently lower in percentage of dolomite. Clay studies, as well as CO_2 and SO_4 determinations, were made in an attempt to explain observed differences in results of the two methods.

MORPHOLOGICAL SIGNIFICANCE OF SOME SELECTED REEF STRUCTURES IN ATOLLS

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Several atolls in the Marshall Islands display, in various degrees of development, a pattern of relatively close-grouped but disconnected reef knolls in a configuration that is conspicuously nonrandom. The reef knolls form a system of successively bifurcating and rebifurcating channels or streams into the lagoon at major atoll passes. Bock Channel, through Ujae Atoll, is the best example in the Central Pacific and shows with some elegance the beginning of the third stage of bifurcation. The parent channel through the atoll rim has been divided into two, then four, and now eight channels.

The symmetry of the pattern of reefs and channels suggests that they are formed (1) by sedimentary reworking during inflow on rising tides, with the resulting bars stabilized by intercalating deposition of coral and algal colonies, or (2) by construction of reef knolls immediately lagoonward of major atoll passes where nourishment from inflowing sea water is maximum and corals grow in

dynamic adjustment to current flow through the constricted zone of the pass itself. In either case the origin is attributed to hydraulically controlled construction rather than to subaerial erosion by streams during emergence, as postulated elsewhere. If sea level remains static for a sufficient time, the entire regime could culminate in the sealing of the passage and the consolidation and widening of the atoll rim at that point. Probable examples of successive stages of passage sealing occur in the Marshall, Gilbert, and Caroline islands.

PRIMARY SPHALERITE-PYRITE-PYRRHOTITE AT THE BALMAT NO. 2 MINE, NEW YORK

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Near Balmat, New York, tabular deposits of sulfide minerals parallel the layering in siliceous magnesian marbles of a metamorphic complex correlated with the Precambrian Grenville series. Sphalerite, pyrite, and locally pyrrhotite, galena, and traces of chalcopyrite replaced carbonate minerals in parts of the siliceous marble units. Contacts between ore and marble are generally diffused over inches to feet.

Textural relations suggest that most of the pyrite formed before sphalerite, which in turn formed before most of the pyrrhotite in the ore bodies. The iron content of analyzed primary sphalerite is homogeneous in hand specimens of ore. Of 170 analyzed sphalerite samples, those associated with pyrite and pyrrhotite contain 10–14 per cent FeS, but those associated only with pyrite contain 6-9 per cent FeS. By use of two systems included under FeS–ZnS–S, it is inferred that the bulk of the sulfide minerals in the No. 2 mine formed above 320° C., assuming a total pressure of 3 kilobars. The temperature of formation of pyrrhotite indicated by the iron content of sphalerite is about 500° C., whereas that indicated by the iron content of pyrrhotite is 330° C. The 500° C. is probably the more reliable temperature estimate.

Gradients in the iron content of sphalerite extend horizontally about 50 feet beyond the association of sphalerite with both pyrite and pyrrhotite into zones where pyrite is the only iron phase.

SUMMER INSTITUTE OF MATHEMATICS AND EARTH SCIENCE FOR SECONDARY-SCHOOL STUDENTS OF HIGH ABILITY AT SAN JOSE STATE COLLEGE, 1960

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A Summer Institute of Mathematics and Earth Science for Secondary School Students of High Ability, sponsored by the National Science Foundation, was held at San Jose State College, San Jose, California, from June 27 to July 22, 1960. Forty commuting students attended, consisting of 14 sophomores, 22 juniors, and 4 seniors (as of 1959–1960). The Institute was designed for enrichment rather than acceleration. Studies in the Earth Science Section centered on water.

The theoretical basis for the dipolar nature of the H_2O molecule was carefully developed. This concept as an explanation of many of the unique properties of water was then developed in such areas as phase relationships, dielectric constant, absorption spectrum, specific and latent heats, solvency, crystal structure and growth, pH, surface tension and others. In the principal part of the course the above concepts were used in explaining such varied geological phenomena as the greenhouse effect, adiabatic lapse rates, nucleation, physical and chemical weathering, erosion, sedimentation, ground water, glaciation, mineral deposition, and the origin and development of life. The thesis that these phenomena would be more efficiently understood by first developing fundamental physical and chemical concepts with water as a focus seemed to be substantiated. Student evaluation of their laboratory, field, and lecture experiences indicated a desire for further study of almost every topic.

ANISOTROPY AND FAILURE IN ROCKS

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An experimental study has been undertaken to determine the effect of anisotropy on the strength and failure characteristics of certain common rocks. Several rocks showing distinct planar anisotropy (bedding, cleavage, or schistosity) were selected for study, and 1-inch by 2½-inch cores were cut at angles of 0°, 15°, 30°, 45°, 60°, 75°, and 90° to the plane of anisotropy. Six to 10 cores of each orientation were prepared for each rock in order to evaluate the effects of a given foliation at several confining pressures, commonly 30, 100, and 300 or 400 bars. All tests were reproduced at least twice under a given set of conditions.

Curves of rupture strength *vs.* inclination of anisotropy are concave upward and roughly parabolic in form. Cores cut normal to the anisotropy generally show the greatest rupture strength, although one rock, Longwood shale, shows the greatest rupture strength in cores cut parallel to bedding. The least-rupture strength is almost invariably shown by specimens cut at 30° to the anisotropy. Higher confining pressures produce a noticeable upward shift of the curves.

The angle of shear fracture was found to be influenced by foliation only in specimens cut at angles less than 30° to the foliation; for all other orientations, shear fractures developed at approximately 30° to the axis of loading. No appreciable effect of confining pressure on the angle of shear fracture was detected.

HIGH-ORDER TRANSITIONS IN MINERALOGY. II: A STRUCTURAL INTERPRETATION

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Nepheline $Na_{8-x}K_xAl_8Si_8O_{32}$ at the sodium end of the solid solution ($x = 0$) consists of identical cells containing eight sodium ions each. As potassium replaces sodium these "solvent cells" coexist with "solute cells," in which p potassium ions substitute for sodium; $p = 1, 2, 3, \ldots$. Various amounts of strain energy are associated with the several types of solute cells; strain energy also develops at the interface between cells of different kinds. When the strain energy exceeds some critical limit, a transition takes place. When 1 out of 32 sodium ions is replaced by a potassium ion ($x = 0.25$), enough strain accumulates to cause the aluminum-silicon framework to switch from a configuration that is assumed to have eight small holes (subpotassic subphase) to one that is known (Buerger, Klein, and Donnay, 1954) to form six small and two large holes. This framework persists, essentially unaltered, throughout the mediopotassic subphase (up to $x = 2$), until every cell contains two potassium ions. The strain involved in introducing solute cells richer in potassium triggers another transition, which results in a framework presumed to provide eight holes large enough to receive potassium ions. This last framework persists in the perpotassic subphase.

PETROLOGIC AND TECTONIC EVOLUTION OF ST. THOMAS AND ST. JOHN, VIRGIN ISLANDS

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The oldest rocks exposed in St. Thomas and St. John, Virgin Islands, are keratophyre flows, with minor spilite flows and keratophyre pyroclastic rocks. This sequence is at least 10,000 feet thick and is thought to be Upper Jurassic or Lower Cretaceous on the basis of sparse Radiolaria. Terrigenous sediments are absent, and the entire volcanic sequence appears to have been extruded on

the sea floor. Mineralogic, chemical, and textural evidence suggests that these rocks are magmatic, not metamorphic, in origin.

Unconformably overlying the keratophyre-spilite sequence is a thick (15,000–20,000+ feet) section of ?Cenomanian augite andesite pyroclastic rocks, volcanic wacke, and radiolarian limestone. Dioritic stocks are of possible early Tertiary age. The structure is relatively simple. Metamorphism is limited to contact aureoles around the stocks.

The keratophyre-spilite sequence may be the oldest Mesozoic formation in the eastern Greater Antilles and may lie directly upon oceanic crust. This sequence was extruded prior to the formation of an oceanic trench, whereas the overlying andesite pyroclastic rocks postdate the initial trench. The structural geology requires compression, not tension, in a north-south direction.

All the magmas were hydrous and contained very little potassium; they are thought to have been derived from a hydrated portion of the earth's mantle. Keratophyre magma was the lowest-melting fraction of hydrated mantle. Spilite and augite andesite are chemically equivalent and achieved their contrasting mineralogies as the result of contrasting environments of extrusion: the former was abyssal, the latter subaerial. None of the magmas were appreciably modified by assimilation of surficial materials.

MULTIPLE GLACIATION, EAST SIDE OF LEMHI RANGE, IDAHO

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Major alpine glaciers occupied east- and northeast-facing valleys heading at elevations of 9700 feet or higher. Small glaciers formed in especially favorable north-facing sites as low as 8600 feet. Peaks at 10,500 to 12,000 feet have been largely destroyed by extensive cirque development, leaving sharp horns and arêtes.

Oldest indications of glaciation, believed to be of Bull Lake age, are remains of looped end moraines present in some of the larger valleys at about 7000 feet. These deposits have been eroded to low, discontinuous mounds with gentle slopes from which limestone boulders have been removed by weathering. Steep-sided, often unbreached end moraines with irregular surfaces on which limestone boulders are numerous rise as much as 100 feet above, and are frequently in contact with, the oldest deposits. These younger moraines, together with recessional, lateral, and medial moraines occupying much of the extent of the larger valleys, correlate with similar records of multiple Pinedale glaciation elsewhere.

Prominent moraines close to or within the largest cirques are of two ages. A thin soil has developed on the outer deposits, and land forms are slightly smoothed. The inner accumulations consist of fresh, unstable boulder ridges devoid of soil. These moraines are correlated with the Temple Lake and Little Ice Age stages respectively.

Depositional land forms of glacial origin are especially well preserved because of local aridity and the consequent small amount of interglacial and postglacial stream erosion.

LATE PENNSYLVANIAN AND EARLY PERMIAN FUSULINIDS OF NORTHEASTERN NEVADA

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The Late Pennsylvanian is represented in the Toana Range by argillaceous limestones and calcareous siltstones of both Missouri and Virgil age. Similar rocks of Early Permian age follow in a conformable sequence and include Wolfcamp and Leonard equivalents. Fusuline Foraminifera are abundant throughout most of the Upper Pennsylvanian and Lower Permian rocks and form a major constituent of many of the beds. The abundantly fossiliferous, apparently complete, gradational

sequence presents an unusual opportunity for the study of the gradual change in fusuline faunas through this time interval.

A developmental series of species of *Triticites* is recognized from the base of the sequence into the lower part of the Permian. One division of this series gives rise to the genus *Pseudoschwagerina*. The schwagerinids are represented by at least two lineages, one leading to *Schwagerina* and the other to *Parafusulina*. The development of septal fluting, from relatively plain septa to the formation of cuniculi, is seen in a gradational series. This development is found in each of the lineages mentioned above. The gradual loss of chomata in each of the lineages is also noted. Other genera recognized in the sequence include *Kansanella*, *Pseudofusulinella*, and *Schubertella*.

SIGNIFICANCE OF CARBONATE DETERMINATIONS IN TILL MATRIX

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Most lithologic investigations of tills lack quantitative data on carbonates (calcite and dolomite) in till matrix. In comparison with coarse fractions of tills, its unweathered matrix has the following advantages: (1) more constant composition, (2) better reflection of relatively distant source rocks, (3) small samples (25–50 gm) are sufficient.

The author and his students have found, during the last 10 years, that differences in carbonate content of till matrix (the −200-mesh grade) served in several instances for distinguishing (1) tills of two glaciers (*e.g.*, the mountain till, with an average of 21 per cent carbonates, from the continental till, with 11 per cent carbonates, in the Waterton area, Alberta); (2) different lobes of the same ice sheet (*e.g.*, the average ratio of calcite to dolomite is .6 in tills of the Georgian Bay lobe, but more than 2 in the adjoining Nottawasaga Bay lobe in Ontario); (3) moraines of the same lobe (the ratio of calcite to dolomite is less than 1.1 in the Wyoming moraine and more than 1.5 in the older two moraines of the same Huron lobe in Ontario); (4) different till layers along Lake Erie and Ontario (results published by author in 1958).

Evaluation of depth of leaching in till requires also knowledge of the amount of carbonates in its matrix.

The amount of carbonates was determined by using the Chittick gasometric apparatus, and calcite differentiated from dolomite by differences in the rate of reaction of these minerals with 20 per cent hydrochloric acid.

MAJOR STRUCTURAL FEATURES OF THE CENTRAL PARTS OF WESTERN UTAH AND EASTERN NEVADA

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Eastern White Pine County, Nevada, and adjacent parts of Utah are underlain by a large dome, younger north-trending structures cutting the dome, and thrust faults.

A northward elongate dome about 40 miles wide and 80 miles long is centered roughly between the Snake and Deep Creek ranges. Precambrian and Paleozoic rocks crop out in crudely elliptical bands around the dome. Regularity of the bands and simplicity of the dome are strongly modified by north-trending structures that are neither simple faults nor simple folds and that underlie the major valleys, the east sides of which generally are dropped 3–5 miles, significantly more than the displacement along range-front faults. The dome is also modified by rootless, near-bedding-plane thrust faults that produce tectonically shortened sections in normal stratigraphic order. Thrust faults are most abundant and most complex on parts of the south, west, and north flanks of the dome; they are absent or buried on the east flank. The most complex thrust faults also occur near the largest north-trending structures.

None of the thrust faults necessarily is a décollement fault correlated from range to range. Possibly they are near-bedding plane thrust faults, following similar weak strata in adjacent ranges, and are localized either near the north-trending structures or around the dome. Repeated, and perhaps reversed, movements along bedding planes in response to movement along possible deep-seated, strike-slip faults appear to provide a partial answer for the abundant omission of beds along the thrust faults, and for the lack of a root area.

HYDROCARBON PHASE EQUILIBRIA: STUDIES IN THE SYSTEM CH_4-H_2O-NaCl-$CaCl_2$ AT PRESSURES TO 1000 PSI

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Water, sodium chloride, calcium chloride, and methane are major components of the fluids that occupy the pore spaces of many sedimentary rocks. These fluids are subjected to variations in pressure, temperature, and concentration during intrastratal fluid flow. The stable phases present in the fluids are controlled by these variables. The nature of the phases present affects the fluid-flow mechanism.

An apparatus was designed for this low-pressure work, consisting of a manifold of known volume and of a rocking and stirred equilibrium cell, both placed in a constant-temperature air bath. With it the solubility of methane in aqueous sodium and calcium-chloride solutions was determined by the pressure-decline method, using the initial and equilibrium pressures, volumes, temperature, and methane-compressibility factor.

The methane solubility was determined at pressures ranging up to 1000 psi and at 25° C.–30° C. temperatures in water, in 0.5 N, 1.0 N, 2.7 N, and saturated NaCl solutions, and in 0.5 N, 1.0 N, 2.7 N, 5 N, and saturated $CaCl_2$ solutions, in addition to a solution that was saturated with both salts. The presence of either salt lowers the methane solubility. It may be estimated that a cubic foot of rock of 20 per cent porosity at 1000-foot depth, saturated with a 50,000 ppm NaCl brine, may accommodate 0.26 mole of methane in solution (5.8 liters at S.T.P.).

In the isothermal, isobaric tetrahedron for the quaternary system, there are three intersecting liquidus surfaces, representing liquid saturated with CH_4, NaCl, and $CaCl_2 \cdot 6H_2O$, respectively. The first and largest of these surfaces is practically coincident with the H_2O–NaCl–$CaCl_2$ face of the tetrahedron.

CRETACEOUS AND CENOZOIC HISTORY OF NORTHEASTERN PACIFIC ECHINOID FAUNAS

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At least 98 genera of echinoids, including "deep-water" types, are known from Cretaceous and Cenozoic of the Eastern Pacific although the sedimentary facies is usually unfavorable to preservation of fossil echinoids. Seventy genera (exclusive of those living only in "deep water") occur in the Northeastern Pacific, with 36 of the latter now living in the region.

Cassidulus, *Catopygus*, *Coenholectypus*, *Echinocorys*, *Echinogalerus*, *Epiaster*, *Heteraster*, *Nucleopygus*, *Phyllobrissus*, *Pygopyrina*, *Salenia*, and *Trochalosoma* in the Northeastern Pacific Cretaceous give a marked Atlantic-Western Tethyan aspect to the faunas. Known Paleocene faunas of the region include only three genera. In the Eocene, *Agassizia*, *Amblypygus*, *Anisaster*, *Cassidulus*, *Eupatagus*, *Lenita* (?), *Linthia*, *Plagiobrissus*, *Schizaster*, and *Spatangus* demonstrate the continuing dominance of the Atlantic-Western Tethyan influence although the endemic *Eoscutella* foreshadows the late Cenozoic abundance of scutellinid clypeasteroids ("sand dollars"). *Metalia* and *Toxopneustes* in the Recent fauna represent a minor Western Pacific element.

During Cretaceous and Early Cenozoic few endemic genera developed among Northeastern Pacific echinoids, but in late Cenozoic one-third to one-fourth (mostly Clypeasteroids) are endemic. This development of endemism seemingly may be correlated with the restriction of the broad middle Cretaceous sea way connecting the Atlantic and Pacific across Mexico and Central America, followed by complete blocking of these connections in late Tertiary, as well as with the progressive restriction of tropical temperatures to their present narrow extent.

ELECTRON MICROSCOPIC OBSERVATION OF VITRINITIC MATERIALS

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Fourteen samples of vitrinitic material selected from coals ranging in rank from subbituminous C to anthracite have been examined utilizing the electron microscope. Two-step carbon replicas were prepared of the sample surfaces. Microchemical analyses have been obtained for all the samples.

The micrographs show that there is an increase in the uniformity of the microfracture pattern with increasing carbon content. This is made evident in three ways: (1) by an increase in the degree of parallelism of the fracture edges; (2) by an increase in the unidirectionalism of the fracture traces; and (3) by an increase, to a limited extent, in the conchoidal type of fracture. Compactness of textures increases with increasing carbon content up through the high-volatile A-rank category. This trend is reversed in the anthracites.

Micrographs of two of the lower-rank materials have revealed the presence of mold spores, bacillia, and crystalline material which may be inorganic.

GROUND DISTRIBUTION OF WIND-BORNE VOLCANIC ASH AS A POSSIBLE INDEX TO POLAR WANDERING

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Study of meteorological data on Recent surface winds and genetically related dune systems of subcontinental size suggests that the use of cross-bedding in ancient aeolian sandstones for determining former positions of the earth's geographic poles could result in highly erroneous interpretations. A less ambiguous guide to past polar locations lies in wind-borne volcanic ash. Salient features of the latter are: (1) flow patterns of winds at altitudes commonly reached by major ash columns (15,000 to 40,000 feet) bear a simpler relationship to the earth's rotational axis than do those of surface winds; (2) frequency of eruption of clouds carrying large amounts of ash to high altitudes is great (33 since 1900); (3) statistical study of the ground distribution of 20 Recent ash falls (plus fallout distributions from near-surface nuclear explosions) demonstrates an east-west orientation maximum accurately locating the present north geographic pole. Study of thickness variations in ancient ash deposits should prove equally useful in locating former pole positions.

Possible difficulties in applying the method to ancient ash deposits are: (1) dispersal by ocean currents of ash deposited in marine environments; (2) erosion of ash prior to burial; (3) deformationally induced thickness changes; (4) difficulty of recognition and correlation of an altered ash deposit over large areas.

Application of the method to a small number of widely scattered Pleistocene ash deposits indicates that within the limits of accuracy of the method, the pole has not shifted since Pleistocene time. A study of Permian ash is strongly recommended.

STAGES OF GLAUCONITE FORMATION IN MODERN FORAMINIFERAL SEDIMENTS

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Five of 325 bottom samples, taken off the southeast coast of the United States by the U. S. Fish and Wildlife Service, contained abundant Foraminifera associated with and containing glauconite.

Inspection of the foraminiferal sediments indicated distinctly different glauconite ranging from the typical dark-green, smooth pellets to very pale-green, porous aggregates of clay. The different types of glauconite also occurred within the tests of Foraminifera and other microorganisms. Magnetic fractions were obtained which contained many tests of recent Foraminifera, which upon solution freed a mold of glauconitelike material.

Analysis by X-ray diffraction of single grains and of composite samples of hand-picked grains showed the material to be mostly 1 M mica-type clay varying in degree of hydration and disorder. Many of the very pale-green aggregates also gave 7 Å and 14 Å diffraction lines. A decrease in sharpness and a shift of the basal mica diffraction line to higher values as well as a decrease in the potassium content and an increase in the water content were directly related to the color change of the clay material from dark green to pale green. Examination of oriented slides following vapor glycol treatment showed that the dark-green glauconite was unaffected but that the pale-green glauconites were expandable.

These samples are interpreted to be composed of various stages of "glauconitization" of clay material associated with the tests of microorganisms.

LANDSLIDE FOLDS IN THE DAKOTA HOGBACK OF NORTHERN COLORADO

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The prominent hogback formed by the east-dipping Dakota group in the Front Range foothills of northern Colorado is folded into numerous arcuate synclinal segments which range from 900 to 2300 feet in length. Most of the segments are bounded on the east by reverse faults. A few are bounded by sharp asymmetrical anticlines. Field evidence indicates that the deformation is limited to the upper beds of the Dakota group—the first sandstone and upper part of the middle shale of the South Platte formation.

Landslides with sliding surfaces about 40 feet below the base of the first sandstone in the South Platte formation caused the structures. The sliding surfaces of the landslides are probably localized in a thin interval of interbedded bentonites which have been called "the first marker." The present sizes of individual synclinal segments are believed to be a function of the sizes of the early undeformed hogback segments between water gaps. The nearly uniform elevation of the toes of the slides suggests that they were controlled by a former level of the Benton shale plains at the eastern base of the hogback. Today the base of the hogback is about 300 feet lower than the toes of most of the landslides.

One large landslide at Ripple Ranch east of Owl Canyon involved only the lower sandstones of the Dakota group—principally the Lytle formation—and slid on a surface in the upper part of the underlying Morrison formation.

SEDIMENTOLOGY OF THE WEST-CENTRAL TACONIC REGION, NEW YORK

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The sedimentology and sedimentary petrology of the west-central Taconic region suggest that the stratigraphic section is structurally autochthonous. Argillites and associated rocks range in age from lower Cambrian through middle Ordovician. Sedimentation probably was not interrupted by subaerial erosion; unconformities appear to reflect nondeposition and/or submarine erosion. Rocks are primarily turbidites, and both slope (clino) and bottom (fondo) facies are present. Turbidity-current and mud-flow criteria are abundant and are clues to the direction and efficiency of these transporting media.

A western source for the Cambrian and lower Ordovician sediments is indicated by directional-current flow markings and facies changes. These rocks were derived from metasedimentary rocks such as now occur in the Grenville complex to the west. The older rocks are first-cycle deposits, but limestone brecciolas, rounded quartz grains, chert, and oölite fragments in the younger rocks indicate sporadic reworking of previously deposited shallow-water sediments. Within the middle Ordovician, the source direction and composition of the sediments changed suddenly. A rising land mass in the Green Mountain area to the east, which was undergoing erosion at that time, is believed to have supplied the detritus for this thick graywacke section.

Although a "Taconic klippe" is not ruled out, the data do not support an inferred eastern basin of deposition.

DELTAITE IS CRANDALLITE PLUS HYDROXYLAPATITE*

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Deltaite, $Ca(Al_3, Ca)(PO_4)_2(OH)_4H_2O$, has been reported only from Fairfield, Utah. The X-ray powder pattern of the mineral from this locality is identical to the powder pattern of crandallite, $CaAl_3(PO_4)_2(OH)_5H_2O$, except for five extra lines on the powder pattern of deltaite. Strunz (1957) said that deltaite is identical to crandallite. The extra lines, whose *d* spacings are 3.43 Å, 2.80 Å, 2.77 Å, 2.62 Å, and 1.93 Å, are at the approximate positions of the strongest lines for hydroxylapatite, $Ca_5(PO_4)_3(OH)$. The structure cell that Larsen (1942) reported for deltaite cannot produce these five lines but can produce the other lines on the powder pattern of deltaite. Larsen did not give a chemical analysis for the single crystal that he used. A mixture of about 70 per cent crandallite and 30 per cent hydroxylapatite would have the theoretical chemical composition of deltaite. Apatite and crandallite are associated with deltaite at Fairfield, Utah, and the three minerals have similar optical properties. Therefore, it is suggested that (1) no good evidence has been reported for the existence of deltaite as a distinct species; (2) the single crystal used by Larsen probably was crandallite rather than deltaite; and (3) deltaite is a mixture of crandallite and hydroxylapatite.

MARINE SEDIMENTARY ENVIRONMENTS IN THE VICINITY OF THE NORWALK ISLANDS, CONNECTICUT

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The Norwalk Islands are a chain of islets in Long Island Sound near Norwalk and Westport, Connecticut. Glacial drift is the source for most of the recent sediments in the area. These sediments range from clay-sized particles to boulders 10 feet in diameter.

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The sedimentary environments are: beaches, tidal marshes, estuaries, and offshore environments. Distribution of recent sediments in these environments, although complex, follows a simple rule: the more an area is protected from wave action, the finer the grain size of its sediment. Protection can be found in deep water, or in the shelter of the islands, or in the estuaries or tidal marshes.

The estuaries, tidal marshes, and protected offshore areas are characterized by grain-size distribution curves that are fine-skewed. Beaches and exposed offshore areas are characterized by distributions that are coarse-skewed. This division, based on skewness values, seems to separate areas of deposition (fine-skewed) from those of erosion (coarse-skewed).

Sand beaches are composed of angular grains and contain an average of 9 per cent heavy minerals (mostly garnet and magnetite). The dominant size-distribution trends on sand beaches are an increase in sorting from the backshore to the lower foreshore and a decrease in mean grain size in the same direction.

Lithification of the marine sediments in the vicinity of the Norwalk Islands would produce a complex sequence of conglomerates, black, pyritic sandy or silty shales, and sandstones with ripple cross-stratification. The sandstones would be classified as feldspathic graywackes.

EARLY GROWTH OF THE SALT ANTICLINES OF THE PARADOX BASIN, COLORADO AND UTAH

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Evaporite rocks in the middle, or salt-bearing, unit of the Paradox member of the Hermosa formation (Middle Pennsylvanian), locally 7000 feet or more thick at the end of salt deposition, have moved into the cores of five narrow northwest-trending salt anticlines that have amplitudes of 7000 feet or more. About 5000–6000 feet of the growth is of late Paleozoic age. The salt anticlines occupy an area about 100 miles long and 30 miles wide near the axis of a deep, northwest-trending depositional trough bordered on the northeast by the Uncompahgre uplift and on the southwest by an old shelf area. Present structural relief of the trough measured on presalt rocks is about 16,000 feet on the northeast and 9000 feet on the southwest. Abrupt structural relief on presalt rocks amounting to thousands of feet seems to be present near some of the salt anticlines.

Stratigraphic units in the upper member of the Hermosa formation (Middle Pennsylvanian), in the Rico formation (Middle and Late Pennsylvanian, the Paradox Valley and Gypsum Valley areas, Colorado), and in the Cutler formation (Permian) thin toward the evaporite cores and are locally absent because of overlap and truncation beneath unconformities. Growth of the evaporite cores in Middle and Late Pennsylvanian time was initiated while the area was covered by a sea. The growth probably began in response to gentle folding accompanying pulses of uplift of the ancestral Uncompahgre. Growth during much of Permian time, after the major uplift of the ancestral Uncompahgre, may have been due largely to differential loading.

STRUCTURE AND COMPOSITION OF POTASSIUM FELDSPAR FROM THE INYO BATHOLITH, CALIFORNIA-NEVADA

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Two granodiorite and four adamellite plutons of the Inyo batholith underlie 120 square miles of the McAfee Ranch quadrangle, California-Nevada. These units were sampled on a 1-mile grid, and the microperthitic potassium feldspar was separated with heavy liquids. Triclinicity was determined from powder, using the angle between the (131) and ($1\bar{3}1$) X-ray peaks. Na and K were determined by flame photometer, and Ca by X-ray spectrometer.

Sixty-four per cent of the samples yield sharp peaks and triclinicities greater than 75 per cent

Twenty-eight per cent display broad peaks and triclinicities less than 50 per cent. In the 50–75 per cent range, several samples have a minor but distinctive monoclinic peak. Except for samples near the contacts, the triclinicities within plutonic units are similar, whereas significant variations occur between units of the same rock type.

Or, Ab, and An contents average 80.3, 17.8, and 1.9 per cent and fall within a relatively narrow range, as shown by standard deviations of 5.5, 4.5, and 1.3, respectively. However, the composition of the microcline from one granodiorite unit is significantly different from another unit of the same rock type. No relation between composition and triclinicity is found.

Field and modal evidence suggests that the sluggish structural ordering to maximum microcline may be controlled by the amount of volatiles available to flux the transformation and the thermal history.

STABILITY RELATIONS OF RIEBECKITE AND RIEBECKITE-ARFVEDSONITE SOLID SOLUTIONS

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Riebeckite, $oNa_2Fe_3^{++}Fe_2^{+++}Si_8O_{22}(OH)_2$, and members of a continuous solid-solution series between riebeckite and arfvedsonite extending as far as the approximate composition $(Na_{2.4}Fe_{0.6}^{++})(Fe_{4.3}^{++}Fe_{0.7}^{+++})Si_{7.7}Fe_{0.3}^{+++}O_{22}(OH)_2$ have been synthesized at pressures up to 2000 bars. Conventional hydrothermal techniques were employed. Physical parameters governing phase equilibria include fugacity (partial pressure) of oxygen, temperature, and vapor (total) pressure. Oxygen fugacity was controlled by copper-, iron- (± silica), and nickel-oxide buffers. The stability field of iron-rich alkali amphibole is bounded by surfaces within an f_{O_2}–P_{vapor}–T volume. The five P_{vapor}–T diagrams presented, each appropriate for a specific oxygen fugacity range, represent projections along the f_{O_2} axis.

At a high-oxidation state where oxygen fugacity is controlled by the hematite–magnetite buffer, pure riebeckite decomposes above 469° C. at 250 bars P_{vapor} and above 515° C. at 2000 bars P_{vapor}. As relative oxidation state diminishes, the amphibole becomes increasingly arfvedsonitic, and its high-temperature stability limit is elevated. With f_{O_2} controlled by the wüstite-iron buffer, riebeckite-arfvedsonite is stable up to 655° C. at 250 bars P_{vapor} and coexists with melt at 712° C. and 2000 bars P_{vapor}.

The experimental data seem to be consistent with field occurrences of iron-rich alkali amphiboles. Hydroxyl-bearing riebeckites are stable at low temperatures and high oxidation states in authigenic, low-grade metamorphic, and pegmatitic environments; in contrast, arfvedsonitic amphiboles appear to have crystallized at lower oxidation states and higher temperatures as primary constituents of alkalic igneous rocks.

SYNTHETIC SCAPOLITES

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Most natural scapolites are considered to be intermediate members between marialite, $3(NaAlSi_3O_8)\cdot NaCl$, and meionite, $3(CaAl_2Si_2O_8)\cdot CaCO_3$. Eitel (1925) synthesized pure meionite. The existence of pure marialite has never been demonstrated, and natural scapolites do not seem to contain more than 75 mol per cent marialite.

Marialite was synthesized dry from mixtures of $Na_2O\cdot 6SiO_2$, Al_2O_3, and NaCl at 1 atm. pressure between 700°C. and 850°C. in runs of 1–2 weeks. Seeding was necessary. Meionite was grown at 850°C. and 1 atm. from SiO_2, Al_2O_3, and $CaCO_3$. X-ray data for synthetic marialite and meionite are:

(hkl)	Marialite $3(NaAlSi_3O_8)\cdot NaCl$		Meionite $3(CaAl_2Si_2O_8)\cdot CaCO_3$	
	$d_{(hkl)}$ in Å	I	$d_{(hkl)}$ in Å	I
(130)	3.818	60	3.834	50
(301)	3.548	30	3.604	30
(112)	3.440	100	3.506	100
(321)	3.058	70	3.073	60
(400)	3.018	40		
(141)	2.730	12	2.746	30
(312)	2.678	35	2.714	40
a	12.075 Å		12.13 Å	
c	7.516 Å		7.69 Å	

Natural scapolites show much greater variations in cell dimensions (a between 12.01 Å and 12.29 Å and c between 7.54 Å and 7.76 Å), which indicates extensive deviations from the marialite-meionite join in the system $3(NaAlSi_3O_8)\cdot NaCl$–$3(NaAlSi_3O_8)\cdot NaHCO_3$–$3(CaAl_2Si_2O_8)\cdot CaCO_3$–$3(CaAl_2Si_2O_8)\cdot CaCl_2$ or the presence of sulfate or potassium ions.

Marialite melts incongruently to albite + liquid at 860° ± 10°C., with the liquid containing more than 90 weight per cent NaCl. The marialite-halite eutectic lies very close to halite and 800°C.

Natural marialites usually form by interaction of sodic feldspars with chlorine-rich solutions. However, albite + halite and analcite + quartz + halite assemblages are known from saline deposits. The absence of scapolites in these environments is attributed to slow reaction rates rather than to a low-temperature limit of stability of marialites.

BURIED EROSIONAL TERRACE ON THE EDGE OF THE CONTINENTAL SHELF EAST OF NEW JERSEY

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Measurements with sub-bottom depth recording equipment on the continental shelf of the east coast off New Jersey have given useful information about sedimentary layering. Bedding planes throughout the area studied dip seaward at moderate angles inshore and at steeper angles near the edge of the shelf. More than 100 miles of the shelf edge has been surveyed, principally between the Hudson and the Wilmington canyons, and a prominent reflecting horizon has been found at about 80 fm depth which appears to be a wave erosional surface corresponding to a recent low strand of sea level. In most places the surface is flat lying and in many places truncates the underlying dipping beds. It can be traced from the edge of the shelf an average distance of 5–6 miles and in several traverses rises abruptly, which is suggestive of beach structure.

A few sediment cores have been taken in an effort to sample the material at the interface. Three that are believed to have done so show sand, pebbles, and shells at the appropriate depth. Some of the larger shell fragments in one core have been examined by Dr. H. G. Richards of the Philadelphia Academy of Natural Sciences and reported to suggest a cool shallow-water environment, "possibly of Wisconsin or early post-Wisconsin age."

These results indicate that Wisconsin sea level was lower than 300 feet as generally accepted. They are in agreement with estimates derived from computations by Ewing and Donn on amounts of Wisconsin glacial ice.

REVISED ESTIMATE OF PLEISTOCENE ICE VOLUME AND SEA-LEVEL LOWERING

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Recent geological exploration of the Canadian Arctic islands shows uplifted beaches and marine sediments at elevations greater than 725 feet. Radiocarbon dates of 7150–9000 yrs. B.P. for shells from two areas indicate post-Wisconsin rebound. Although continued study is in progress, these data suggest a thicker ice cover for much, if not all, of the Arctic islands than has been usually accepted. Nearly all the Arctic coast of Siberia was well glaciated, as evidenced by new Soviet exploration including discoveries of drift beneath a fairly thick cover of recent sediments. If simultaneous glaciation is assumed for this area, the estimate of Siberian Pleistocene ice must be increased.

Recent observations of the maximum ice thickness on Greenland and Antarctica imply greater thicknesses for the principal continental Pleistocene ice sheets. On the basis of increased areas and thicknesses, a recalculation of glacial sea-level lowering suggests an increase of 100–200 feet more than the −300-foot value generally quoted. Published work of Fisk and McFarlan and Heezen tend to support this view. More recent observations of J. Ewing and Fray off eastern United States, showing an 80-fm erosional bench associated with cool, shallow-water fossils identified tentatively as Wisconsin support further an increased glacioeustatic fall in sea level. A radiocarbon date of greater than 30,000 years from an ambiguous assemblage of broken shell material leaves the absolute age of this bench still undetermined.

ORIGIN OF BEDDED CHERTS, TURBIDITES, AND VOLCANIC ROCKS OF THE CARBONIFEROUS OF NORTHERN INDEPENDENCE RANGE, NEVADA

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Sedimentary rocks of eugeosynclinal facies are present in the northern Independence Range, Elko County, Nevada (Wildhorse and Bull Run quadrangles). These rocks include nine formations, Mississippian in part, about 9000 feet in maximum thickness. They were folded and thrust from the northwest after Mississippian and prior to Miocene times. Principal lithic types include (1) argillaceous mudstone, (2) bedded cherts, (3) sandstone and conglomerate, and (4) andesite lavas. Inferred environments of deposition, based on micro- and megastructures, are as follows:

Originally, the bedded cherts were pelagic accumulations of siliceous organic debris, mostly radiolarian fragments, covering as much as 100 square miles of sea floor. Bedded cherts grade from those clearly composed of solid organic debris to those in which the finer radiolarian fragments have merged into a featureless silica continuum. Diagenetic partial solution and interstitial crystallization, accompanying compaction, is considered the essential mechanism of lithification of the bedded cherts.

The sandstone and conglomerate, which show graded bedding and flute casts, consist mostly of poorly sorted, poorly rounded quartz grains in an argillaceous matrix. They, as well as the Radiolaria, were deposited intermittently, whereas the pelagic clay (now mudstone) accumulated more continuously. The cherts are products of repeated, relatively brief flourishings and settlings of siliceous plankton. The coarse, detrital sediments (turbidites) contain directional structures indicating flow from the west. Layers of pebbly mudstone (tilloids) record chaotic submarine slides into the deep-water site of sedimentation.

MORPHOLOGY AND HYDROLOGY OF A GLACIAL STREAM

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The processes by which a valley train is formed by a glacial stream were studied on the northeast flank of Mt. Rainier, immediately below the present terminus of Emmons Glacier.

White River channels ranged in width from 0.7 to 60 feet, in mean depth from 0.03 to about 2.08 feet, and mean velocity from 0.3 to 9 fps for discharges of 0.01 to 430 cfs. Width and depth of channels in noncohesive materials change by scour and deposition, as well as by flow at different depths in pre-existing channels.

Pebble counting demonstrated that median diameter of valley-train materials decreased 60 mm in a distance of 4200 feet, owing to selective transportation. White River data suggest that for coarser materials the "sixth power law" of competency should be the 7.8 power law.

Erosion and deposition on the valley train caused an average net change in elevation of +1.2 feet during 1958 and −0.12 foot in 1959. White River has a braided pattern at high flows and a "meandering" pattern at low flow. Braiding was observed in degrading reaches. It is suggested that braiding is caused by movement of bed load in such quantity that some is deposited within the channel, resulting in the diversion of flow from one channel into others.

Although the regimen of the glacier has long-term effects in providing debris to the stream, short-term effects of weather and runoff determine hydraulic characteristics, rate of deposition and erosion, and the channel pattern.

SIGNIFICANCE OF A BRAIDED CHANNEL PATTERN

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Explanations offered for the cause of braided patterns include erodible banks, rapid and large variation in discharge, slope, and abundant load. The common element in all explanations seems to be a movement of bed load in such quantity or of such coarseness that there is deposition within the channel, causing the diversion of flow from one channel into other channels in a valley wide enough to provide freedom to braid.

Although examples of braiding by an aggrading stream are common, White River and Sunwapta River, Alberta, have reaches in which degradation took place while the stream had a braided pattern. The conclusion is reached that both braided and meandering reaches can occur along the same stream, which may be aggrading, poised, or degrading. The pattern alone does not conclusively define the regimen of the stream.

COMPARATIVE RATES OF LATE GLACIAL AND POSTGLACIAL UPLIFT IN NORTH AMERICA

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Radiocarbon dates pertinent to postglacial Lake Algonquin in the Upper Great Lakes permit construction of curves of uplift for many localities. These dates suggest that Lake Algonquin occurred in very early post-Valders time, terminating prior to 10,000 years ago. Curves for North Bay, Sault Ste. Marie, and Cape Rich, Ontario, show continuous but exponentially decreasing uplift since Lake

Algonquin time. Pre-Algonquin uplift appears to have been stepwise. Such curves permit determination of the age of the Chippewa-Stanley low stages and the elevation of a contemporary low stage in Lake Superior basin. The curves require some revision of the chronology of Great Lakes' history.

Fragmentary data from raised marine strand lines in Arctic Canada suggest similar rates and magnitudes of uplift along the Arctic coast, in the Canadian archipelago, and in areas formerly overlain by the Ellesmere-Baffin Island ice sheet. Such data when complete will aid greatly in determining the size and shape of Wisconsin ice sheets.

ANALYTICAL PROBLEMS IN DETERMINING HYDROCARBONS IN SEDIMENTS

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The procedure generally applied in determining hydrocarbons in ancient sediments involves extraction of pulverized sample with volatile solvent(s), recovery of the extract residue by forced evaporation of the solvent(s), removal of interfering substances such as sulfur, and separation of hydrocarbons from the residue by elution chromatography. The effects upon this process of several important variables were:

Extraction. Samples of 10-micron median size gave up twice as much extractable hydrocarbons as 30-micron samples; 5-micron samples gave 2.75 times more extractables than 30-micron samples. Using a specially designed apparatus, extraction was 90 per cent complete in 10 hours and 99 per cent in 20 hours. Benzene is preferred over mixed solvents for extraction of hydrocarbons.

Isolation. Evaporation of benzene (or cyclohexane) from 10- to 150-milligram portions of residue having approximately 200°C. initial boiling point is performed with considerable uncertainty owing to sample volatility. This is a major factor presently limiting precision and accuracy of the determination.

Chromatography. Extract residues usually are resolved on silica gel having 32 Å pores only below 0.1 per cent loading. Using a layer of 170 Å gel over the 32 Å gel increases the adsorbent capacity to 2 per cent.

Precision. Ninety replicate determinations from among 33 samples provided standard-deviation estimates for a single measurement vs. level of the measurement of S = 3, 32, and 400 ppm at 10, 200, and 5000 ppm, respectively.

This paper reports also the specific conditions used in obtaining the measurements for one geochemical study.

CHEMICAL CHARACTERISTICS OF WATERS FROM SELECTED MONOLITHOLOGIC TERRANES

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Study of both new and published analytical data shows that the ratio $Ca \times HCO_3/Na \times SiO_2$, all constituents expressed in parts per million (ppm), separates water from carbonate-rock terranes (ratio > 20) from waters from other rock environments (ratio < 20) studied in 89 per cent of 558 examples tested. Elimination of 38 high-silica waters reportedly from the Ocala limestone in Georgia increases to 94 per cent the proportion to which the stated relationship applies.

The ratio (ppm) $Na \times Mg/Ca$ plotted on probability paper gave a separation of basaltic from granitic waters in 70 per cent of 126 samples tested.

A new flexible graphic device, illustrated with slides, provides patterns that are characteristic of

waters from carbonate rocks, serpentine, and basaltic or granitic rocks. Other separations appear in some plottings. Patterns are characteristic for river waters draining essentially monolithologic terranes, as well as for ground waters.

Results obtained are already of interest to geochemical prospectors and should be applicable in various terrane and ground-water studies. They are preliminary to detailed consideration of the origin of mineral constituents dissolved in ground water and their relation to rock and mineral weathering.

SULFUR-ISOTOPE GEOLOGY OF VEIN-TYPE AND SANDSTONE-TYPE URANIUM DEPOSITS

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Sulfur-isotope-abundance data from more than 500 sulfur-bearing samples of vein-type and sandstone-type uranium deposits have been collected to determine the importance of bacterial processes in the localization of ore deposits and to provide additional knowledge concerning the distribution of sulfur isotopes in several geologic environments. The isotopic data for sulfides are as follows:

	Vein-type deposits	*Sandstone-type deposits*
Range of S^{32}/S^{34} ratios	22.10–22.35	21.18–23.40
Percentage variation	1.2	10.0
Range of percentage variation/deposit	0.1–1.0	0.1–6.1
Mean percentage variation/deposit	0.5	2.5
Mean S^{32}/S^{34} ratio/deposit	22.22	22.66

The relatively narrow range of S^{32}/S^{34} ratios, near the meteoritic value (22.21), for primary sulfides of vein-type deposits, is indicative of magmatic hydrothermal mineralization.

Sulfides associated with sandstone-type deposits characteristically exhibit broad S^{32}/S^{34} ratio variations and are commonly enriched in S^{32} relative to meteoritic sulfur. The evidence suggests that the mineral constituents were deposited from ground-water solutions in local reducing environments. The precipitating agent was hydrogen sulfide, variably enriched in S^{32}, generated by sulfate-reducing bacteria.

A mechanism involving the bacterial reduction of a finite quantity of sulfate is proposed to account for the anomalously low S^{32}/S^{34} ratios for sulfides of the Woodrow mine.

A cursory study of the C^{12}/C^{13} ratios of carbonates associated with sandstone-type deposits indicates that, in general, the quantity of calcite carbon derived from organic material is small compared with that derived from sedimentary carbonates in the enclosing sediments.

PROPOSED CLASSIFICATION OF VOLCANICLASTIC ROCKS

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Volcaniclastic rocks are divided here into autoclastic (fragments that either formed and stayed within volcanic vents, or that formed during movement of lava flows), pyroclastic (fragments formed by volcanic explosion and extruded from vents), and epiclastic (fragments formed by weathering and erosion of lithified or solidified volcanic rocks). Fragments have grain-size limits similar to nonvolcanic epiclastic rocks. Any clastic type may become mixed in any proportion.

Lapilli sizes are 2 mm to 64 mm; the upper size limit of ash is 2 mm. Lapillistone (new term) is preferred instead of lapilli-tuff. "Primary" and "reworked" are used with pyroclastic names to indi-

cate nonmovement or significant movement of fragments after depostion, as "primary tuff" and "reworked tuff." Tuff is used if neither origin can be confirmed.

Nongenetic terms are based only upon size and presence of volcanic fragments.

	Autoclastic	*Pyroclastic*		*Epiclastic**	*Equivalent, nongenetic terms*
		Primary	*Reworked*		
256 mm–	Flow breccia Intrusion breccia	Pyroclastic breccia and agglomerate		Epiclastic volcanic breccia	Volcanic breccia
64 mm–		Lapillistone		Epiclastic volcanic conglomerate	Volcanic conglomerate
2 mm–	Tuffisite	Coarse	Tuff	Epiclastic volcanic sandstone	Volcanic sandstone
1/16 mm–		Fine		Epiclastic volcanic siltstone	Volcanic siltstone
1/256 mm–				Epiclastic volcanic claystone	Volcanic claystone

* Add adjective such as "tuffaceous" to rocks with pyroclastic fragments included.

VOLCANIC CLASTIC ROCKS OF THE JOHN DAY FORMATION IN THE MONUMENT QUADRANGLE, NORTH-CENTRAL OREGON

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The John Day formation in the Monument quadrangle, north-central Oregon, can be divided into three parts, similar to but not strictly the same as those of Merriam (1901):

(1) The lower member is chiefly red siltstone and claystone containing altered shards and relatively fresh feldspar crystals. (2) The middle member is varicolored, composed predominantly of shards altered to zeolite and montmorillonite. Primary crystals include sodic plagioclase, sanidine, quartz, a little pyroxene, and rare hornblende. Within beds the constituent grains are unsorted, elongate fragments unoriented, and fossils disarticulated. Some beds are crowded with structures resembling (insect?) borings. (3) The upper member contains abundant glass shards, both siliceous and basaltic, some marginally altered to montmorillonite. Also present are corresponding crystals of quartz and sanidine, sodic and calcic plagioclase, and relics of olivine. Bedding is lacking in much of this member, although layers of primary and reworked tuff, volcanic siltstone, and conglomerate are found locally in its upper portions.

Much of the material of the formation probably was carried by wind from areas of fresh ash deposits. The lower member in addition received much material from a saprolite which had developed on the pre-existing surface. The only slight alteration of shards in the upper member could mean a distinct time break between it and the middle member, and the presence of the basaltic pyroclastic debris raises the question of whether the Columbia River basalt eruptive activity might not already have begun in neighboring areas.

TWO TILLS IN SOUTHERN CONNECTICUT*

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A large borrow pit excavated by Lake Chamberlain, northwest of New Haven, Connecticut, during reconstruction of a dam in 1959, exposed two tills in direct superposition. The younger till represents

* Published with the permission of the Director, Connecticut Geological Survey

the last glaciation of the district. Measurement of three directional parameters on each till, coupled with observation of the surface of contact between the two tills, supports with high probability the assumption of glacial movement from north or northwest, later followed by movement from the northeast. An episode of oxidation and valley cutting, intervening between these movements, is likely but is not firmly established.

MICROORGANISMS ATTACHED TO ORDOVICIAN CORALS

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Attached to cateniform and phaceloid Montoya corals are 12 distinct types of tiny organisms, thus far observed only from sections. Three types of colonial tubes are found, two types of arched bodies, one of numerous thin plates, one of few thick fibrous plates; a spherical body on a short neck with thick-walled bodies within suggests a cyst or spore capsule; another, bifurcated, suggests echinoderm pedicilariae. There are wartlike bodies of two different types of texture. They are possibly widespread but have escaped previous notice. Similar forms have been found on Ordovician corals from Utah and Norway. Thus far positions of these remains even in phyla are uncertain; seemingly probable taxonomic assignments have been opposed by specialists in those groups. They will nevertheless be described in the hope of calling wider attention to these forms, so that their taxonomic position may be resolved.

RELATIONSHIPS OF SOME COLONIAL ORDOVICIAN CORALS

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Extension of a descriptive study of corals of the Montoya led to revised concepts of morphology and evolution. Fibrous walls rather than septa are primitive; trabeculae are derived from fibrous structures. Primitive cerioid types (*Lichenaria* and *Saffordophyllum*) have common walls of trough-like V-shaped fibers on continuous axial planes; only the change in direction marks the boundary between individual corallite walls. A new genus shows such walls with the axial plane broken into short discrete units and the units finally shortening to linear axes around which fibers form cones; these are monacanthine trabeculae in *Nyctopora*. Further specializations involve (1) broadening of walls to a porous coenenchyme (*Calapoecia*), and (2) development of solid massive bacular rods (*Coccoseris*).

In *Foersteophyllum* there develops an axial plate, leaving original fibrous material as "sclerenchyme." From here one line leads to rugosan types, where the axial plate, really double, may divide and form epithecae around individual corallites; here specializations occur in septa. Another line develops pores leading to *Paleofavosites* and higher Favositidae, where the plate may divide into "primary walls." Wall structure indicates that *Saffordophyllum* is homeomorphic with the Favositidae in development of pores.

Holothecae of cateniform types suggest holothecae in ancestral cerioid genera. A granular poikilopoasm, formed at calicular bases, ranges from a lining to discrete spheres; such spheres form the columella of *Billingsarea*.

Present results suggest a close relationship among the genera studied, inconsistent with separation into Rugosa and Tabulata.

CORRELATION OF "LATE" WISCONSIN TILLS IN KNOX COUNTY, OHIO, WITH THOSE IN WESTERN OHIO ON THE BASIS OF SOILS

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Knox County lies on the eastern side of the Scioto Lobe not far from the major re-entrant in the glacial boundary, near the geographic center of Ohio. Interpretation of the county's glacial deposits is complicated by irregular distribution of morainic areas and varied orientation of crest lines within these areas, produced by the relief of buried hills and the effect of a major drainage system cutting across the deposits.

Soils have provided an answer to the problem of correlation. Though soil scientists map only soils of the Alexandria catena in the area of "late" Wisconsin till in Knox County, two distinct soils have been identified, whose differences, though not great, are consistent within the restricted areas where each occurs. The shallower of these two soils, which is characterized by shallower, weaker structural development and thinner, less persistent clay coatings, lies to the west of a distinct soils boundary, which separates the two soils. This boundary may be followed southwest out of the county to near Circleville, where it merges with the line separating the shallow Miami 6A soils from the complex of deeper, better developed Miami 60-shallow Russell soils. This line, which lies outside the Reesville-Farmersville moraines, is one of the major soils boundaries in western Ohio and can be traced westward to beyond the Ohio State line.

Thus, by the use of small but persistent differences in the soils, a correlation of moraines is made possible, both within Knox County and between Knox County and the areas to the west.

Fe_2O_3 IN CHLORITES

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By assuming Fe_2O_3 to represent oxidized FeO, Winchell reduced many leptochlorites to orthochlorite composition. Since then Fe_2O_3 in chlorites has been generally viewed with suspicion by mineralogists; Hey, in his recent classification, considered any chlorite containing more than 4 per cent Fe_2O_3 as oxidized and divided the chlorites into an unoxidized and an oxidized series on this basis. However, a current study of chlorites shows that most ferroan chlorites contain more than 4 per cent Fe_2O_3, and that in many some or all of the Fe^{+3} is necessary for structural balance. In one chlorite that contained 8.70 per cent Fe_2O_3, all the Fe^{+3} was necessary to give the octahedral layers enough positive charge to balance the negative tetrahedral charge. If all the Fe_2O_3 in this analysis is calculated as FeO in the formula, the number of octahedral positions is 6.27, instead of 6.00.

Secondary oxidation would require one (OH) converted to (O) for each Fe^{+2} raised to Fe^{+3}, but a comparison of O and Fe_2O_3 contents of many chlorites showed no such correlation.

Many chlorites are formed by alteration of other minerals, some of which may contain Fe^{+3} ions, and it is not unlikely that these would be incorporated in the chlorite structure.

It is concluded, therefore, that Fe_2O_3 in chlorites is not necessarily the result of secondary oxidation, and abnormal, but should be considered a normal constituent unless there is definite reason to consider it derived from FeO by oxidation.

SOLUBILITY OF QUARTZ IN WATER IN THE TEMPERATURE INTERVAL FROM 25°C. TO 300°C.

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At room temperature and pressure a highly supersaturated solution was obtained by continuously rotating quartz grains (20–100 mesh) in water in a polyethylene bottle. The amount of ionic silica in

solution continuously increased to a maximum value of 395 ppm in 370 days. The ionic-silica value then decreased, and the final measured value was 300 ppm 490 days after the start of the experiment. This is still a supersaturated solution, even in respect to silica gel. Equilibrium solubility values were obtained in experiments conducted in metal bombs at higher temperatures and pressures. Equilibrium is shown by identical results for runs of different duration and by the precipitation of quartz from initially supersaturated solutions. In sealed bombs in the presence of liquid and gaseous H_2O the solubility of quartz is 25 ppm at 84°C., 165 ppm at 165°C., and 435 ppm at 240°C. At 15,000 psi water pressure the solubility is 70 ppm at 100°C., 320 ppm at 200°C., and 925 ppm at 300°C.

CLADOCERA FROM THE EEMIAN INTERGLACIAL OF DENMARK

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Twenty-five species of chydorids were recovered from a section at Herning in Jutland. All 25 species occur in Denmark at present. The species that are most common now were also most common in the Eemian Interglacial, and the species that are rare or uncommon now were rare or uncommon then. All the 8 additional species of chydorids presently occurring in Denmark are regarded as rare or uncommon. Extrapolation from the chydorids to the Cladocera in general suggests that the present fauna of Western Europe is an old, stable assemblage that was displaced by the ice and returned *en masse* when conditions again became suitable. The species have likewise been stable morphologically over this interval. This study represents the first detailed analysis of a cladoceran fauna from before late-glacial time.

NONCALCAREOUS MARINE ALGAE FROM THE UPPER ORDOVICIAN OF THE LAKE WINNIPEG REGION, MANITOBA*

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Restudy of four distinctive morphological forms of noncalcareous algal remains was based on collections made by G. Winston Sinclair of the Geological Survey of Canada from localities between McBeth Point and Cat Head on Lake Winnipeg, Manitoba. These rare hydrocarbon algal films are preserved in light-yellowish-gray aphanitic limestones and dolomites of the Cat Head member of the Red River formation. Evidence based on marine invertebrates indicates Richmondian, hence Late Ordovician, age. Plants of this type probably grew in shallow water but were undoubtedly buried at considerably greater depths within the shelf zone.

The four distinctive morphological types which constitute the flora are: (1) a laminar thallus branching in one plane; (2) a stalked form with linear, leaflike appendages borne spirally; (3) an articulate form composed of small cylindrical units, each of which tapers at the node; and (4) a form with a main axis along which are pinnately arranged lateral appendages. Comparisons with contemporary algal forms indicate that all the morphological patterns exhibited by the fossils are most closely duplicated in the red algae.

The cumulative evidence from the morphological diversity attained by early Paleozoic marine plants focuses attention on the problem of plant evolution. A dual pattern of evolution for plants, one within marine waters and one in fresh water, is a possibility. Evolution in the sea may have been more rapid and left a poorer record of plant structure now only gradually being discovered.

* A contribution from the Museum of Paleontology, University of California, Berkeley, Calif.

LAND SUBSIDENCE IN THE SAN JOAQUIN VALLEY, CALIFORNIA, RESULTING FROM WATER APPLICATION

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Shallow land subsidence on the west side of the San Joaquin Valley, California, presents a most serious engineering problem in the design, construction, and maintenance of the proposed main aqueduct of the California Water Plan. Differential settlement resulting from water application could destroy grade and disrupt lining of canals traversing subsidence areas. Means of locating and identifying these areas and methods of precompacting subsidable soils prior to construction are currently being studied by the California Department of Water Resources, in co-operation with other agencies.

Three separate but related geologic approaches to identifying potential shallow subsidence areas consist of studies of source area, debris flow, and aerial photographs. These investigations are correlated with known subsidence areas, soil-test results, and control test ponds. Properties of debris flows are being analyzed for settlement characteristics. Besides efforts to develop aerial-photograph criteria identifiable with subsidence, aerial photography is utilized to delimit debris flows and assist in source-area mapping.

A series of sample holes was drilled in both compactible and noncompactible soils. These soils were tested to determine gradation, density, moisture content, specific gravity, plasticity, and consolidation. Test results indicate that, individually, these characteristics can be used to define partially a soil that would compact when supplied with a sufficient quantity of water. By combining these characteristics in a nomograph, compactible soils can be competently defined.

TECTONIC FRAMEWORK OF SOUTHERN YUKON AND NORTHWESTERN BRITISH COLUMBIA, CANADA*

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Northwestern British Columbia, southern Yukon, and southeastern Alaska constitute two zones of crystalline rocks separating three northwestward-trending belts of unmetamorphosed stratified rocks, each with different tectonic histories. The eastern crystalline zone forms the backbone of Pelly Mountains and Cassiar Mountains, and the western zone forms the axis of Coast Mountains.

A miogeosyncline prevailed in the eastern belt from late Proterozoic until middle Devonian time and was succeeded by eugeosynclinal conditions in late Devonian and early Mississippian time.

A eugeosyncline existed in the central belt from Permian to about the end of Triassic time. Subsequently volcanism ceased, and by the late Jurassic the belt was broken into two separate basins. The intervening area later became the approximate site of the Atlin horst.

Eugeosynclinal conditions persisted in the western belt from Ordovician to Cretaceous time. In the Cenozoic the Yakataga geosyncline formed along the coast of the Gulf of Alaska.

Ultramafic rocks are most common in Permian and Mississippian greenstones.

The eastern crystalline zone was established at least by early Triassic time and the western zone some time before the Permian. Subsequent to their initiation these zones were the prinicpal loci of plutonism and uplift. Consequently, they controlled the distribution and character of Mesozoic strata and, in part, the manner of their deformation.

Although parts of the region were deformed earlier, orogeny was widespread in mid-Cretaceous time. Cenozoic deformation occurred locally in all three belts. The structural pattern is heterogeneous. Major faults subdivide the belts into blocks of differing tectonic style.

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ORDOVICIAN STROMATOPOROIDEA OF NORTH AMERICA

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Ten genera and 35 species of North American stromatoporoids are described and figured, including 10 new species, all in the family Labechiidae.

The late W. A. Parks made the first attempt, in 1910, to clarify knowledge of Ordovician stromatoporoids; he described or redescribed 18 species. In the past half century several new forms have been added, and some clarification of the structure and identification has been made. Only about 76 species of Ordovician stromatoporoids are known in the world; 48 species are known from North America, and the writers have restudied, described, and figured 35 of the most important of these. The study was made largely from authentic specimens, holotypes, syntypes, or topotypes. The descriptions and illustrations were made from thin sections. Stromatoporoids first occur in the Middle Ordovician of Isle La Motte, Vermont, and continue to the top of the Ordovician in most areas where Ordovician rocks occur; in many places they occur as reefs.

UPPER PALEOZOIC STRATIGRAPHY AND SEDIMENTATION OF NORTHERN ARKANSAS

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Upper paleozoic strata of northern Arkansas constitute an atypical miogeosynclinal facies of cyclically deposited, locally tuffaceous sandstone, siltstone, shale, chert, and limestone. Nine post-Boone formations studied (three yet unnamed) include 17 major lithologic subdivisions ranging in age from middle Mississippian to late early Pennsylvanian.

Strand oscillations across a slowly subsiding shelf locally marred a regionallly continuous depositional sequence which crops out in the Boston Mountains between the Ozark dome and Ouachita geosyncline. Areas of inundation were created by gentle warping and faulting and by differential compaction accentuated in argillaceous sections around reefs and structural highs. Additional stratal complexities reflect intermittent reef development, land climate changes, volcanic-ash influxes, and periodic contemporaneous deformation and deposition.

Lithofacies analysis suggests a northern and/or northeastern (Canadian Shield?) source for most terrigenous detritus. Environmentally significant key stratal horizons include (1) Batesville and Atoka (Winslow) basal conglomerates, which lack fragmented limestone even where resting unconformably on limestone, (2) basal Hale, upper Hale, and middle Bloyd sections with subaerially fragmented limestone gravel, (3) upper Hale, middle Bloyd, and basal Atoka quartz pebble-sandstone intervals, and (4) immediate pre- and post-Pitkin sections of cherty tuffaceous shale.

Critical to correlation and determination of the Mississippian-Pennsylvanian boundary is recognition of a thick post-Pitkin pre-Hale shale and limestone interval which coincides with the youngest Arkansas occurrence of the *Archimedes* facies fauna. This fauna was subsequently eliminated by early Morrowan environmental changes associated with widespread sand deposition.

PHASE RELATIONS IN THE HIGH-ALUMINA PORTION OF THE SYSTEM CaO–Al_2O_3–SiO_2

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An isothermal approach, utilizing a combination of a modified quench technique and solid-state sintering, was used to establish the general location of the mullite-corundum boundary and to

determine the compatibility relations of the crystalline phases. The results of this isothermal study indicate that the mullite-corundum boundary in the system CaO–Al_2O_3–SiO_2 terminates at the invariant point at which mullite, corundum, anorthite, and liquid are in equilibrium. The location of this point at a composition of 15.6 per cent CaO, 36.5 per cent Al_2O_3, and 47.9 per cent SiO_2 at 1512° C. was reported in the original work of Rankin and Wright and is supported by this investigation.

The isothermal investigation of the high-alumina portion of the system CaO–Al_2O_3–SiO_2 indicated that a primary field existed for the synthetic compound calcium hexaluminate ($CaO \cdot 6Al_2O_3$). Previous investigators in the Soviet Union had inserted a field of calcium hexaluminate and located its invariant point with anorthite and corundum. By omission, investigators in the United States cast doubt on the stability of calcium hexaluminate. The results of this investigation establish calcium hexaluminate as a stable phase having a primary field in this system and indicate a revision of the corundum-calcium hexaluminate boundary and of the invariant point at which anorthite, corundum, calcium hexaluminate, and liquid are in equilibrium. This invariant point is located at 28.0 ± 0.5 per cent CaO, 39.7 ± 0.5 per cent Al_2O_3, and 32.3 ± 0.5 per cent SiO_2 at 1405° ± 5° C.

Rb-Sr AND K-A AGES OF THE PRECAMBRIAN OF WESTERN MONTANA AND WYOMING

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Minerals from the Dillon granite, Pony gneiss, and Cherry Creek gneiss of southwestern Montana give Rb–Sr ages of about 1500 m. y. over a northeast-southwest distance of about 60 miles. Total-rock Rb–Sr analysis of the Dillon granite gives the same age. A few K–A determinations also give about this age. Some evidence indicates that this metamorphic terrain may be older. Considerably younger Rb–Sr ages are found in the Precambrian near Cretaceous-Tertiary intrusions.

A complex Rb–Sr age pattern in different mineral types is observed in the Teton Range, Wyoming. It suggests, however, an age of 2500 m. y. and may correlate with the 2600 m. y. metamorphism in the Beartooth Range to the north.

STUDIES IN THE SYSTEM $CaCO_3$–$MgCO_3$–$FeCO_3$

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Isothermal sections at 700°, 750°, and 800°C. under 15 kb total pressure were obtained using a squeezer-type apparatus. Iron can be maintained in the ferrous state because in this apparatus at these pressures the sample is essentially void-free and kept isolated by the tight seal maintained by the pistons. Complete reaction of mixtures throughout the system has not yet been attained at lower temperatures.

The system contains two two-phase and two single-phase areas at the temperatures of this study. One single-phase region extends a short distance into the ternary system along the full length of the $MgCO_3$–$FeCO_3$ binary join. The other extends as a thin sliver from dolomite along the ternary join $CaMg(CO_3)_2$–$CaFe(CO_3)_2$, curving upward and enlarging into the $CaCO_3$ apex after traversing approximately two-thirds of the join.

The hypothetical compound $CaFe(CO_3)_2$, not known in nature, lies in a two-phase field even at 800° C. Solid solubility, particularly in the vicinity of the ternary join, is only slightly affected by temperature. Iron substitution in the dolomite structure appears to be as extensive in lower-temperature natural samples as at 800° C.

A quantitative emission spectrographic procedure for analysis of Ca, Mg, Mn, and Fe in 1-mg dolomite samples is described, and cell sizes are correlated with composition for about 24 samples. The $CaCO_3$ content, which can be determined to ± 1 mol per cent at a 67 per cent confidence level, ranges from 49 to 56 mol per cent.

SUBSOLIDUS PHASE RELATIONS IN THE SYSTEM $CaCO_3$–$MgCO_3$

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The top of the solvus outlining the two-phase field of magnesian calcites and dolomite is at a temperature of 1075° C. at the composition $Ca_{57}Mg_{43}$, and above the solvus a single-phase region extends from $CaCO_3$ to $CaMg(CO_3)_2$. The solubility gap between $CaMg(CO_3)_2$ and $MgCO_3$ is considerably larger, and solubility of Ca^{++} in $MgCO_3$ and Mg^{++} in $CaCO_3$ is limited at 1100° C. Cation disorder in stoichiometric dolomite becomes observable at approximately 1000° C. and is complete at approximately 1200° C., at which temperature $CaMg(CO_3)$ has the calcite-type structure. All evidence indicates a continuous (higher-order) transformation over this 200° C. interval. Disorder is enhanced by substitution of Ca^{++} for Mg^{++} in dolomite; the most Ca-rich dolomite showing any order exists at the top of the solvus. Thus, in addition to the thermal disordering in pure dolomite, a region in which disorder takes place at constant temperature is observed in passing from dolomite to magnesian calcite at temperatures above the solvus.

Simple substitutional disorder and mixed-layer effects are observed in quenched samples near dolomite in composition. These high-temperature equilibrium states have previously been observed in naturally occurring metastable low-temperature protodolomitelike materials.

TEACHING A GEOLOGY COURSE AT SECONDARY LEVEL

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A "normal" elementary course in geology is being presented to eleventh and twelfth graders in a private secondary school. The course is patterned after college courses, and standard college texts are used (Gilluly in physical, Schuchert in historical). Considerable local field work, map reading, mineral and rock identification, and photograph use are part of the course.

Response to the course has been most favorable. More than half of the graduates have taken college geology courses. It is a relatively inexpensive science course requiring comparatively little equipment, it is flexible with no specific exams or defined content, and the field work appeals. Many principals and headmasters are interested in such a course. Geology majors have an adequate background to fill in with other science teaching if necessary.

Compared to college teaching the chief drawbacks for the secondary-school teacher are: slower pace, lack of library and research facilities, lack of contact with other geologists, and teaching limited to elementary level.

Chief advantages are: freedom within the subject, small classes, free time for unrestricted research or travel, and students with younger, more flexible, and enthusiastic minds.

DEPOSITIONAL ENVIRONMENT OF THE EOCENE COAL DEPOSITS OF WASHINGTON

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The principal coal deposits of the State of Washington were formed during Eocene time in swamps near the eastern margin of a north-trending eugeosyncline. A general westward regression of the strand from early to late Eocene time with periodic eastward marine transgressions resulted in intertonguing of marine strata with continental coal-bearing rocks. Basaltic and andesitic flows and pyroclastic rocks are intercalated with the coal-bearing sedimentary rocks, and many of the coal beds contain volcanic ash. In some areas thick accumulations of volcanic rocks formed topographic highs that interrupted the continuity of the coal basins.

DETERMINATION OF CAVITY PATTERNS IN LIMESTONE

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Most engineering structures founded on limestone are to some extent affected by the cavities that are present in the bedrock. The size and orientation of these solution cavities are necessary factors to consider in the choice of site and structure design. The careful placing of diamond-core drill holes makes it possible to determine the approximate size and extent of such cavities. During the construction of a dam or large plant, it is necessary to have much more detailed information, so that the cavities can be treated to provide for water-tightness and support. It is possible to make the necessary detailed geologic drawings by analyzing the jointing in the bedrock. Cavities that will affect construction are developed along the joints in the bedrock, and this determines the pattern of the dissolved openings. Other structural features such as bedding and faults may determine the position and size of solution cavities.

REINVESTIGATION OF THE SUITABILITY OF MAGNETITE FOR HELIUM AGE DATING

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The He/U + Th dating of magnetite has produced many concordant ages (Hurley and Goodman, 1943). Discordant ages result from excess or deficient helium with respect to the total alpha emission.

High helium ratios may be due to primary helium trapped in magnetite or associated minerals.

A magnetic concentrate from the Sudbury norite containing less than 50 per cent magnetite yielded an age of <36,000 m. y. (Hurley and Goodman, 1943). When the writers concentrated magnetite from the norite they obtained an age of 2500 m. y.

Low helium ratios may result from recrystallization, thermally activated diffusion, or superficial uranium and thorium contamination.

Acid leaching experiments and autoradiography have been used to determine the location of uranium and thorium in magnetite. In some cases, acid leaching removes contaminating uranium and thorium in two steps, the first indicating removal from grain surfaces and the second from fractures or partings in the magnetite. Tumbling and washing removed only surface contamination. Acid leaching provides a more effective technique for removing contaminating uranium.

A slight rise in the alpha activity after the initial drop indicates a zone of exsolution below the surface where uranium has moved out to the grain boundaries and been precipitated.

Alpha counting, fluorimetry, and gamma-ray spectrometry were used to analyze for uranium and

thorium. A Diatron 20 mass spectrometer has been adapted for static operation under ultra-high vacuum conditions to determine helium by isotope dilution.

WATER PRESSURE AND TOTAL PRESSURE IN METAMORPHIC ROCKS: SYSTEM $NaAlSi_2O_6$-H_2O-ARGON

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The pore fluid in any metamorphic rock contains more than one component; thus the partial pressures of the components are less than the pressure P_S on the solid mineral grains. The relative importance of partial and total pressure on the stability of analcite has been investigated at 500° C. in analyzed mixtures of water and argon. Results are reported in terms of total pressure on the fluid mixture and "equilibrium pressure" $P_{E_{H_2O}}$ of water. The P_E of a component of a mixture is the pressure of the pure component that has the same temperature and chemical potential as that component in the mixture. The $P_{E_{H_2O}}$ of water in the water-argon mixtures was found by measuring the P-V properties of the system water-argon at 500° C. These results were used to determine the equilibrium boundary between analcite and albite plus nepheline at 500° C. in terms of $P_{E_{H_2O}}$ and total fluid pressure (equal to P_S). This boundary passes through the points

P_S	635,	1000,	1500,	2000	bars
$P_{E_{H_2O}}$	635,	800,	1060,	1375	bars.

The dependence of $P_{E_{H_2O}}$ on P_S along an equilibrium boundary can be predicted from the volume changes in the reaction; this predicted dependence is in excellent agreement with that measured.

In regional metamorphism, compositional gradients in the pore fluid which are not colinear with the thermal gradient may cause isograds to cross one another if one isograd is defined by a reaction which evolves CO_2 and another by a reaction which evolves H_2O.

CLAY-MINERAL FACIES DEVELOPMENT IN RECENT SURFACE SEDIMENTS OF THE NORTHEASTERN GULF OF MEXICO

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Three rivers supply the bulk of clay detritus to the northeastern Gulf of Mexico. The mineralogy of the clay reflects the weathering vs. parent-rock interplay in the drainage basins. In the western drainage basins, erosion and transportation of essentially unaltered montmorillonitic sediment prevails. Eastward, weathering becomes more effective, and kaolinite gradually becomes more abundant in the soils and river clays. Consequently, the Mississippi River is contributing a montmorillonitic clay-mineral suite, and the Apalachicola River is contributing a kaolinitic suite. The Mobile River lies geographically between the other two rivers and contributes an intermediate clay-mineral suite.

Wind-induced and oceanic currents distribute the residual suspended sediment over much of the floor of the eastern gulf. Montmorillonitic clay from the Mississippi River blankets most of the area, but in the northeastern corner, a strong influx of kaolinitic clay from the Apalachicola and Mobile rivers is evident. A broad area where the two clay types merge has been quantitatively divided into a succession of clay-mineral facies.

The dominant features observed are caused by the mixing of clay from two distinctly different weathering regimes. Alterations in the clays produced by marine waters are minor and take the form of: (1) slight reduction of the montmorillonite/kaolinite ratio; (2) reduction of interlayer water in montmorillonite; and (3) reduction in swelling capacity of degraded vermiculite.

GEOPHYSICAL STUDIES IN THE MARYLAND PIEDMONT

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Aeromagnetic and aeroradioactivity data are being used to aid geologic mapping in several 7½-minute quadrangles in the piedmont of southwestern Maryland. The combined geophysical data delineate all known rock units and suggest the subdivision of several of the units:

Magnetic Level in Gammas (Arbitrary Datum)

Aeroradioactivity level in counts per second	1110–1500	1500–2000	2000–3100
150–400	metamorphosed mafic volcanic rocks Harpers phyllite (terrace gravels)	Triassic diabase diorite gabbro	serpentine ultramafic rocks metabasalt
400–550	Triassic arkose	Wissahickon formation (schist and phyllite)	Wissahickon formation (subunits)
550–750	Ijamsville phyllite Triassic shale Wissahickon formation (subunit)	Harpers phyllite (subunits)	Wissahickon formation (subunits)

Field investigation of the subunits indicates lithologic differences which would be difficult to trace without geophysical data in this area of deeply weathered and poorly exposed rocks.

Contacts of most of the units can be located by the aeroradioactivity data, commonly within 500 feet and usually within 1000 feet. The aeromagnetic data provide information on near-surface structure, especially the attitudes of contacts.

A detailed gravity profile was surveyed by Martin Kane across the trend of the units west of Rockville. It has been used to compute the shapes of the bodies of mafic rocks. A larger mafic mass may underlie the entire area at a depth of 5000 to 10,000 feet.

RE-EVALUATION OF THE RUSSIAN PAPER COAL*

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The discovery of a cuticular coal in Indiana prompted the reinvestigation of the famous Russian paper coal. Since 1860, when Auerbach and Trautschold reported its existence, misconceptions have grown around the Russian *Papierkohle*.

Although the Moscow Basin covers an area of more than 30,000 sq. km, the coal seams are discontinuous, lenticular deposits and thus do not underlie the entire area. Only one seam, a lignitic coal, is mined extensively. This coal is composed chiefly of durain, is extremely high in ash, is relatively high in volatile matter, and contains pockets of cannel coal. Local concentrations of plant cuticles in the upper layers of this seam form the famous *Hautkohle* or *Papierkohle*. The writer found that only four exposures of such papery layers were cited—at Milenino, where Jeremejev discovered them in 1853, and at Ssatinka, Malovka, and Tovarkova. Although the thickness of the entire coal seam may reach 3.5 m, the reported thickness of the papery layers ranges from 1.2 to 8.0 cm.

Auerbach and Trautschold used the name *Blaetterkohle*, not *Papierkohle* as generally reported. The perforated membranes were recognized as plant cuticle by Zeiller in 1880; previous authors had

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referred to them as epidermis. The cuticles represent twigs of ligulate lycopsids. Three species each of *Lepidodendron* and *Bothrodendron* have been differentiated by the present author.

MINOR ELEMENTS IN PHOSPHORITES OF THE PHOSPHORIA FORMATION

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Analysis of 60 samples representative of phosphorites of the Phosphoria formation in Idaho, Wyoming, Montana, and Utah gives the following modal and maximum contents of minor elements:

Spectrographic Analyses
(Charles Annell and Joseph Haffty, U. S. Geological Survey, analysts)

Element	Mode (Weight per cent)	Maximum (Weight per cent)	Element	Mode (Weight per cent)	Maximum (Weight per cent)
Ag	0.0003	0.003	Nd	0.03	0.03
As*	.004	.02	Ni	.01	.1
B	<.005	.01	Pb	<.001	.003
Ba	.01	.03	Sb*	.0007	.004
Be	<.00005	.0003	Sc	.001	.003
Cd	<.005	.03	Se*	.001	.007
Co	<.001	.003	Sr	.1	.1
Cr	.1	.3	U†	.009	.021
Cu	.01	.03	V	.03	.1
Ga	<.001	.001	Y	.03	.1
La	.03	.1	Yb	.001	.003
Mn	.003	.03	Zn	.03	.03
Mo	.003	.03	Zr	.003	.01

* Arithmetic average of colorimetric analyses by H. E. Crowe, J. E. Swick, and R. R. Beins
† Arithmetic average of chemical analyses by G. Edgington, A. Schrenk, W. Tucker, G. Daniels, and R. Moore

Chromium is the most abundant of all the minor elements. It is greater than or equal to the vanadium content in all the samples. Eight samples contain 0.3 per cent chromium and high amounts of most of the other elements. One of these contains 0.8 per cent total minor elements, the greatest amount of all the samples, of which Cr, V, Mo, Ni, Cu, and Zn make up 0.5 per cent, and As, Sb, Se, U, Cd, Ba, and Zr are present in their respective highest or higher than average amounts. The high chromium samples, which are also the highest in total minor elements, contain 3.6 per cent organic matter compared to an average of 2.1 per cent in all the phosphorites.

EARLY MISSISSIPPIAN FORAMINIFERA OF THE UNITED STATES

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Calcareous and arenaceous Foraminifera are extremely abundant, diverse, and have wide geographic distribution as well as stratigraphic range in lower Mississippian Kinderhookian-Osagian rocks in the United States. Emphasis is placed on the arenaceous Foraminifera faunas in the Rock-

ford limestone, sub-Rockford, and upper Rockford shales of Indiana; Welden limestone of Oklahoma; Chappel limestone of central Texas; Sappington algal-foraminiferal association; and Lodgepole limestone of southwestern Montana. The total arenaceous fauna includes 16 genera and 49 species among the families Astrorhizidae, Saccamminidae, Hyperamminidae, Reophacidae, Tolypamminidae, and Lituolidae. Fourteen species have been recognized among the three genera of calcareous Foraminifera, *Granuliferella*, *Endothyra*, and *Plectogyra*.

The close relationship that exists between foraminiferal faunas and associated lithologies reflects environmental control. Environmental studies by Rich, Edie, Gutschick, and Perry and others indicate that early Mississippian Foraminifera are associated with shoal algal banks (Sappington formation), shoal open marine edge of barrier banks (light-colored endothyroid-calcarenites of the Redwall limestone of Arizona, Humboldt oölite of Iowa and others), cool shallow aerated waters of the open-marine-shelf environment (Rockford, Welden, and Chappel limestones), and transitional basin-edge environment beyond the open marine shelf extending into the basin (dark-colored clinoform beds of the Lodgepole limestone).

CRETACEOUS COLORADO GROUP WEST OF THE BOULDER BATHOLITH IN MONTANA

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The Cretaceous Colorado group, in 13 sections west, south, and east of the Boulder batholith in western Montana, thickens rapidly westward from 2500 feet in the Disturbed Belt (Rocky Mountain Front) to 12,000 feet in the Clark Fork Valley near Drummond and Garrison.

Western Coloradoan sections are divided into six formations, three of Early Cretaceous and three of Late Cretaceous age. Late Albian, Early Turonian, and Late Turonian molluscan faunas provide correlations with parts of the Blackleaf and Marias River formations in the Disturbed Belt.

Salic volcanic detrital and pyroclastic debris derived from the Idaho batholithic area is a major component of post-Middle Albian Coloradoan rocks. Unlike bentonitic sections to the east, western sections are dominated by siliceous mudstones (porcellanites) and volcanic wackes, similar to those in the Aspen formation of western Wyoming. Tongues of shale homotaxially equivalent to the Skull Creek and lower Carlile shales project westward into the thick lithic-volcanic arenite sequence.

Adjacent Laramide tectonic-volcanic activity began during deposition of Upper Albian strata, which are overlain by disconformable, paralic Upper Turonian oyster-reef-bearing sandstone and calcarenite. Uplift and erosion of Cretaceous strata over the Boulder batholith preceded region-wide deposition of Upper Turonian pebbly sandstone. Succeeding regressive deposits, more than 5000 feet thick and equivalent to most of the Niobrara, were tilted prior to deposition of locally derived limestone conglomerates. The conglomerate sequence contains lenses of andesitic-latitic debris, which suggests equivalence, at least in part, with the Elkhorn Mountains volcanic rocks east of the Boulder batholith.

ORIGIN OF TALUS AND SCREE IN NORTHERN VIRGINIA

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Deposits of talus and scree composed of quartzite boulders are numerous in the Blue Ridge in the outcrop belt of the Chilhowee group of Early Cambrian and Cambrian (?) age, particularly on the Antietam quartzite. Scree occurs in two situations; in one it lies on the quartzite bedrock from which it is derived; in the other it commonly exhibits a crude size differentiation related to slope, is on softer rocks, and has moved downslope from its source into hollows and valley heads. The scree

generally consists of angular boulders averaging 14 cm in diameter. Except in a thin surface layer the boulders are mixed with sand.

Evidence of recent movement of scree found in several places consists of differences in the lichen cover, trees tilted or partly buried by boulders, and fresh scarplets crossing the scree. It is believed that scree develops in areas of steep slope where the bedrock is tough, brittle, and resistant to chemical weathering. The scree must be maintained by erosion on or at the base of the slope. Intense runoff associated with severe storms has sorted boulders and moved some areas of scree, particularly in hollows. The scree is produced, moved, and weathered by processes active today, although the rates of formation and weathering may have varied in the past.

BASEMENT ROCKS OF SOUTHERN OKLAHOMA

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Basement rocks of Precambrian and Middle or Early Cambrian (?) age were investigated in 16,000 square miles of south-central and southwestern Oklahoma. Samples from 150 widely spaced wells, in some of which as much as 3000–12,000 feet of igneous rocks has been penetrated, were used in conjunction with outcrop studies in the Wichita and Arbuckle mountains to interpret and map six principal rock series.

The youngest basement rocks are dated at 500–550 m. y. They include the Wichita leucogranite as well as rhyolite flows and pyroclastic sedimentary rocks at least 4500 feet thick, which together cover about 55 per cent of the region. Undated basalt, spilite, and andesite flows more than 1000 feet thick underlie the rhyolite; and this group is underlain by metagraywackes, meta-arkoses, and argillite. Undated gabbro and diorite occur in the axial part of the Wichita Mountain uplift.

Biotite-microcline granites of the Arbuckle Mountains, dated at 1350 m. y., occur with diorite in the eastern quarter of the Southern Oklahoma region.

All the basement rocks except gabbro subcrop beneath the Reagan and Honey Creek formations, dated by trilobites as late Cambrian (Franconian). In pre-Reagan time the greatest structural uplifts were in the Arbuckle province and in the area of metasedimentary rocks along Red River, whereas the greatest stability was in the extensive tract of thick rhyolites between the Wichita and Arbuckle mountains. Areas of maximum Paleozoic folding, however, are underlain and partly controlled by these stratiform rhyolite flows.

BORATE MINERALS IN PERMIAN GYPSUM OF WESTERN OKLAHOMA

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The borate minerals probertite, ulexite, and priceite are described from horizontally bedded gypsum of Middle Permian age at 12 localities in west-central Oklahoma, recording their first occurrence in the United States outside the well-known deposits of California, Nevada, and Oregon.

Probertite is the most abundant mineral, occurring in cores from the Cloud Chief gypsum in the Weatherford area of Custer County, and in five quarries in the Nescatunga member of the Blaine formation in Blaine County. Ulexite occurs with probertite in some of the cores and in one of the quarries, whereas priceite has been found only at one outcrop locality.

The gypsum beds occur with bedded anhydrite in relations that indicate that gypsum is forming by hydration of anhydrite during the modern cycle of weathering. Borate minerals are found only in massive gypsum, generally less than 5 feet and at no place more than 9 feet away from the anhydrite interface. They are concentrated along crudely defined bedding surfaces as nodules commonly a quarter of an inch to half an inch in diameter and exceptionally as much as 4.5 inches in diameter.

Boron for the borate minerals is derived from the anhydrite, which contains 60–700 ppm B_2O_3

and averages 248 ppm for 25 samples. Corresponding samples of gypsum uniformly contain less than 50 ppm B_2O_3, the boron having been excluded and concentrated in the borate minerals. As much as a third of the boron in the anhydrite is contained as water-soluble inclusions.

MICRO-CROSS-LAMINATION IN UPPER KEWEENAWAN SEDIMENTARY ROCKS OF NORTHERN MICHIGAN

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Micro-cross-lamination is the dominant type of stratification in the fine-grained sandstone and siltstone units in the Keweenawan sedimentary rocks of northern Michigan. Except for its size it is identical to "trough" or "festoon" cross-bedding and is therefore significantly different from ordinary ripple lamination. The average set of micro-cross-lamination is 2.5 inches wide, 0.5 inch thick, and 8 inches long. This structure is also extremely abundant in other fine-grained sedimentary rocks, although in many places it is partly obscured by weathering or diagenesis and may not appear as typical cross-stratification. Its presence in apparently homogeneous sedimentary rocks has been revealed by staining the iron or calcite cement. It is therefore probable that micro-cross-lamination represents a fundamental mechanism often associted with the deposition of fine-grained sediments.

Associated sedimentary structures clearly indicate that micro-cross-lamination originates in a shallow-water environment repeatedly subjected to subaqueous erosion. Observations of similar structures in modern streams and flood plains suggest that it develops from migrating cusp ripples.

Micro-cross-lamination constitutes an excellent criterion for paleocurrent direction. Its value is greatly enhanced by its abundance and size; several complete sets can easily be collected in an oriented hand specimen, sawed in numerous sections, and analyzed in the laboratory.

LATE CENOZOIC TECTONICS AND VOLCANISM OF THE YELLOWSTONE REGION, WYOMING, IDAHO, AND MONTANA

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The eastern Snake River plain and the Yellowstone Plateau form a continuous deep structural basin filled by Pliocene and Quaternary rhyolites and basalts and outlined by indipping mountain blocks, some raised chiefly in Miocene, but most raised in Pliocene and Quaternary time. Some blocks truncate older Laramide uplifts, others are partly coextensive with them.

In Pliocene time, Yellowstone Plateau was deeply covered by welded tuffs. The central part, 30 miles across, then subsided, probably into a magma chamber, and the caldera was filled by Quaternary rhyolite flows. Large-scale volcanism continued into Wisconsin time; the youngest flows may be Recent. The late Quaternary flows of the western Yellowstone Plateau issued from a crestal fissure zone which joins the Teton Range with the Madison or Centennial Range.

The Snake River downwarp trends northeast across most Laramide and younger structures yet shares little of their deformation. Most of the lavas of the east end of the downwarp are upper Quaternary basalt. Island Park basin, however, is an early Quaternary caldera, 18 miles across, formed in rhyolite tuffs and flooded by rhyolite and basalt flows.

The silicic rocks of the Yellowstone-Snake River province are alkaline, high in iron, low in alumina and calcium, and form a bimodal suite with the basalts. They may have originated chiefly by differentiation of basalt. Rhyolites of Yellowstone Plateau may be the crust of an extrusive basaltic lopolith, ponded in a structural basin, whereas rhyolites of Island Park may be the crust of a stock-like mass of basalt which broke through to the surface.

RADIOACTIVE TRACER STUDY OF THE SEPARATION EFFICIENCIES OF ROCK AND SEDIMENT ORGANIC MATTER IN LABORATORY CHROMATOGRAPHIC COLUMNS

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Chromatography is one of the principal methods of analysis in organic geochemical investigations. To perform accurate analyses the analyst must know the separation efficiencies of the components to be separated in a given chromatographic system.

Samples of the viscous Athabasca petroleum and portions of the organic extract of a recent sediment sample (obtained from Long Island Sound, New York, from a depth of approximately 35 feet) were mixed with each of the following C^{14} labeled compounds: n-octadecane-1-C^{14}, n-octadecyl-1-C^{14} alcohol, stearic-1-C^{14} acid, and phenanthrene-9-C^{14}. The mixtures were eluted from alumina- and silica-gel columns with the same series of solvents: (1) n-heptane, (2) carbon disulfide, (3) carbon tetrachloride, (4) benzene, (5) methylene chloride, (6) chloroform, (7) diethyl ether, (8) pyridine, (9) ethyl acetate, (10) methyl alcohol, (11) ethyl alcohol, (12) acetic acid, and (13) formic acid. Radioactivity was usually recorded in more than one of the eluate fractions of a given mixture. For example, the asphalt—n-octadecane-1-C^{14} and the recent sediment—n-octadecane-1-C^{14} mixtures showed high activity in the n-heptane fractions and weak activity in some of the subsequent fractions, such as in the pyridine fractions. Similarly, the asphalt—stearic-1-C^{14}-acid mixture yielded weak counts in the benzene fractions and strong counts in the acetic- and formic-acid fractions. Radioactivity was mainly restricted to the acetic- and formic-acid fractions in the elution pattern of the recent sediment—stearic-1-C^{14}-acid mixture.

It is often difficult to attain sharp separations during the chromatography of rock and sediment organic matter. The writers recommend that in routine geological studies the chromatographic fractions be analyzed by suitable means to ascertain their composition and to identify their impurities.

PRECAMBRIAN ROCKS OF THE EASTERN UINTA MOUNTAINS—A CLASSIC RELATIONSHIP

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The Red Creek quartzite (older Precambrian) was crenulated, injected with mafic magma, refolded and metamorphosed, injected with pegmatite, faulted, and deeply eroded before the overlying Uinta Mountain group (younger Precambian) was deposited.

Several rock types characterize the Red Creek quartzite: metaquartzite predominates; mica schist and amphibolite are common; green chrome-bearing quartzite is a characteristic minor constituent. Other minor associated rocks are chloritic schist, carbonate rock, epidiorite, quartz-albite gneiss, and pegmatite.

Pelitic mineral assemblages in the Red Creek quartzite contain quartz, muscovite, staurolite, garnet, kyanite, and biotite. These minerals indicate dynamic metamorphism at great depths and high temperatures; kyanite, which is unknown in igneous thermal aureoles, is especially significant.

The Uinta Mountain group was deposited on the deeply eroded Red Creek quartzite on a surface of low rolling relief. Local relief was perhaps a few hundred feet; nearby relief was perhaps mountainous. The basal conglomerate of the Uinta Mountain group and other higher conglomerates contain pebbles, cobbles, and boulders derived from the Red Creek.

The unconformity at the base of the Uinta Mountain group is substantiated by: (1) truncation

of the complex structure of the Red Creek quartzite by the basal beds of the Uinta Mountain group; (2) much greater structural complexity in the underlying Red Creek quartzite than in the overlying Uinta Mountain group; (3) high-grade regional metamorphism in the underlying Red Creek and no metamorphism in the overlying Uinta Mountain group; (4) pebbles, cobbles, and boulders in the Uinta Mountain group derived from the Red Creek quartzite.

DEHYDRATION SERIES IN THE SYSTEM $CaSiO_3$–SiO_2–H_2O

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Hydrothermal studies show a dehydration series involving CSH (1), tobermorite, xonotlite, gyrolite, reyerite (truscottite), silica, and wollastonite. The synthetic equivalents of gyrolite and reyerite have ideal compositions very close to $2CaO \cdot 3SiO_2 \cdot 2H_2O$ and $3CaO \cdot 5SiO_2 \cdot 1\frac{1}{2}\ H_2O$ respectively.

With rising temperature at saturated steam pressures, the following reactions take place:

(1) CSH (1) or tobermorite + silica → gyrolite (+ H_2O)	150° C.
(2) tobermorite → xonotlite + gyrolite + H_2O	170° C.
(3) gyrolite + silica → reyerite + H_2O	<180° C.
(4) gyrolite → reyerite + xonotlite + H_2O	220° C.
(5) reyerite → xonotlite + silica + H_2O	355° C.
(6) xonotlite → wollastonite + H_2O (above 5000 psi)	400° C.

Data on (1), (2) and (6) confirm results of previous workers.

All the P_{H_2O}–T curves or bands are steep except that involving the breakdown of tobermorite. This crosses the curve representing the breakdown of gyrolite at a quintuple point. None of the reactions has been reversed, and the temperatures indicated are approximate and based on runs of about 4 weeks duration. For much shorter times somewhat higher temperatures are needed to cause the reactions, and conversely in much longer runs slightly lower temperatures might ultimately suffice.

The silica was usually amorphous, cristobalitic or quartz with a mineralizer and therefore of higher activity than quartz alone. Up to 2 per cent of alkali fluorides facilitated the formation of gyrolite, and this is probably related to the fact that apophyllite in many cases accompanies gyrolite in amygdules. Reyerite forms very easily, and the rarity of reported occurrences, compared to those of xonotlite, gyrolite, and opaline silica, suggests that some workers may have overlooked it.

GEOLOGIC FRAMEWORK AND HYDROLOGY OF INTERMONTANE VALLEYS OF THE GREAT BASIN

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Future exploitation of ground water in the arid lands of the Great Basin requires a detailed knowledge of the geologic framework of the alluvial aquifers. The classical concept that the structural basins were filled with material from local mountain masses by interior drainage appears to be invalid in some localities. There are indications that some basins were filled with materials brought in by a through-flowing drainage system. The position of certain volcanic-rock masses suggests that they blocked the ancient rivers and thereby constituted a dominant control on the sedimentation in major basins.

Alluvial deposits in Arizona basins may be divided, from base upward, into three types: (1) gravel, sand, and silt laid down on the basement rocks; these deposits in places are indurated and locally are deformed by tectonic activity; (2) lacustrine and flood-plain fine-grained deposits; these constitute a large part of the basin sediments; (3) surficial deposits of gravel, sand, and clay that were laid down mainly as thin broad alluvial fans; this surficial deposit is highly permeable and constitutes

a vast ground-water reservoir, but rapid decline of water tables indicates it may be depleted in the near future.

Total thickness of the basin deposits probably ranges from a few thousand feet to more than 5000 feet. The highly permeable surficial unit is about 500 feet thick. In comparison, the underlying several thousand feet of fine-grained alluvium has a lower permeability and will not yield large amounts of water. Construction of wells deep into the basin deposits is necessary to produce large amounts of water.

USE OF AMPHIBOLES AND PYROXENES FOR K-Ar DATING

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To determine the general applicability of amphiboles and pyroxenes for K–Ar dating, a suite of 10 hornblendes and three pyroxenes has been analyzed, giving the following K–Ar ages:

Tinquaite, Mont Royal, Quebec (pyroxene)	$100 \begin{smallmatrix} +25 \\ -80 \end{smallmatrix}$
Granite, Ellicott City, Maryland	300 ± 10
Tonalite, Wheaton, Maryland	315 ± 15
Granite, Rockport, Massachusetts	310 ± 10
Granite, Oak Bay, New Brunswick	330 ± 15
Syenite, Chicoutimi, Quebec	700 ± 30
Granite-gneiss, Crossnore, North Carolina	840 ± 25
Storm King granite, Bear Mtn., New York	910 ± 25
Baltimore gneiss, Devault, Pennsylvania	960 ± 30
Grenville gneiss, Dill Station, Ontario	940 ± 30
Gabbro, Kenogami, Quebec (pyroxene)	1240 ± 75
Sudbury gabbro, Neelon Township, Ontario (pyroxene)	1670 ± 100
Amphibolite, Dryden, Ontario	2370 ± 80

Precision errors shown only; constants used: $\lambda_e = .585 \times 10^{-10}$ yr^{-1}, $\lambda = 5.30 \times 10^{-10}$ yr^{-1}.)

When compared with ages of coexisting biotite, feldspar or zircon determined previously by Carnegie Institution and Massachusetts Institute of Technology, all show good geological concordance. No evidence is found for the existence of excess "trapped" radiogenic argon in amphiboles.

The potassium content of the 10 amphiboles ranges from 0.40 per cent to 2.1 per cent, and of the pyroxenes from .094 per cent to 0.16 per cent. From this sampling, it seems likely that most amphiboles and pyroxenes of Paleozoic age and older contain sufficient potassium to date by present techniques.

When biotite is present in the rock, hornblende samples of greater than 95 per cent purity cannot in general be obtained, as shown by X-ray-diffraction studies of the above samples.

CARBONATE AGGREGATE-CEMENT PASTE REACTIONS

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Compositional variations occurring when carbonate aggregates react with Portland cement paste were studied to gain information on chemical reactions causing distress in concrete. Previous research indicates that high insoluble residue-argillaceous dolomitic rocks with poor service records react in alkaline concrete environments producing silicified shells in the aggregate.

Carbonate aggregate cubes of varying mineral composition and service records placed in cement-paste bars were held in a distilled-water bath at 55° C. for 3 months. After reaction the aggregate

and cement were sampled at specific distances from the interface and analyzed by chemical and X-ray methods.

Chemical analyses indicate that silica behavior is variable; silica increases in shell zones of lower to moderate insoluble residue aggregates and decreases in the adjacent cement. Higher insoluble residue aggregates show the opposite effect. In either case a visible, resistant, silicified shell forms. Magnesium migrates from the shell; some calcium migrates into the shell from the cement.

X-ray analyses of the silicified shell indicate a decrease in quartz and dolomite and an increase in calcite. In bordering cement pastes hydrated alite (impure tri-calcium silicate, the major compound in cement) decreases.

Silica migration is believed to be controlled by the relative concentration of available silica in adjacent aggregate and cement as affected by local pH conditions. Dolomite-hydroxyl ion reaction explains dolomite decrease and calcite increase in the shell. Very low insoluble residue aggregates which do not extract silica from cement pastes lack sites for silica precipitation and have excellent service records.

MICROTEXTURE OF ARTIFICIALLY CONSOLIDATED ARAGONITIC MUD

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Electron micrographs of artificially consolidated aragonitic muds from the Bahama Banks show that a complete change in particle structure and texture takes place even in mud compressed only 1 day. Natural-state samples of the mud were consolidated under various conditions, 30°–400° C., 15–5000 psi, from 2 hours to 63 days. The needlelike morphology of the original grains is first modified by rounding of the ends, followed by increasing coalescence of the particles to form larger grains. The boundaries of the particles in well-consolidated mud interfere with one another to give a mosaic texture closely resembling that of natural, aphanitic limestone. Therefore, it is concluded that muds of the Bahama type cannot be excluded as a possible source of such limestones because relict needle-like structures have not been observed in them.

Although in many samples the aragonite inverted to calcite, the textural changes appear to be related not to the transformation but to a recrystallization of one or the other phase.

SCHODERITE, A NEW PHOSPHOVANADATE MINERAL FROM NEVADA

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A new phosphovanadate mineral, schoderite, $2Al_2O_3 \cdot V_2O_5 \cdot P_2O_5 \cdot 16H_2O$, occurs as yellowish-orange microcrystalline coatings associated with wavellite and vashegyite along fractures in phosphatic cherts of the Vinini (?) formation near Eureka, Nevada. Schoderite is monoclinic, probably of the prismatic class, and forms microscopic bladed crystals that are tabular, parallel to the face (010), and elongate parallel to the c axis. Unit cell dimensions for schoderite are: $a_o = 11.4$, $b_o = 15.8$ and $c_o = 9.2$ Å, $\beta = 79°$. The mineral is biaxial positive, with $2V = 60°$ (calculated), $\alpha = 1.542$, $\beta = 1.548$, $\gamma = 1.566$; Y = b. X-ray powder patterns show the following spacings and intensities for the stronger lines: 15.8 Å—4, 11.1 Å—5, 9.6 Å—2 7.9, Å—10.

Schoderite loses up to four waters at room temperature in a dry atmosphere and converts to a lower hydrate, $2Al_2O_3 \cdot V_2O_5 \cdot P_2O_5 \cdot 12H_2O$, which is termed metaschoderite. Metaschoderite may be rehydrated to schoderite by contact with water. Dehydration is accompanied by shrinkage of the unit cell along the b axis to 14.9 Å. The β angle remains unchanged for both hydration states, since a_o and b_o are unaffected by state of hydration. Metaschoderite is biaxial negative, $2V = 73°$ (calculated), $\alpha = 1.598$, $\beta = 1.604$, $\gamma = 1.626$; Z = b. Strongest X-ray lines are 14.9 Å—6, 11.1 Å—5, 7.5 Å—10, 3.02 Å—3. Chemical analyses, X-ray crystal data, and differential thermal analyses together with infrared spectra will be presented.

The mineral is named in honor of William P. Schoder, research chemist employed for many years by Union Carbide Nuclear Company.

DISTRIBUTION OF TRACE ELEMENTS BETWEEN CLAYS AND ZEOLITES FORMED BY ARTIFICIAL WEATHERING OF SYNTHETIC BASALTS

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In an attempt to determine the fractionation of various trace elements by the structure of the crystals forming, gels and glass of gross basaltic composition containing 0.5 per cent by weight of B, Ga, Ni, Rb, and Sr were reacted hydrothermally in sealed systems at 350° C. and 15,000 psi. The experiments were repeated introducing the trace elements in the solution. The analcite and montmorillonite formed by this process were separated from each other and each analysed for the above trace elements using X-ray fluorescence and emission spectrography. B was evenly distributed between the two crystalline phases, although most of the B went into the solution phase. Ga was equally distributed between the clay and zeolite with little or no Ga going into solution. In comparison to analcite, montmorillonite shows a marked preference for Ni to the extent that it acts as a collector for the element. Montmorillonite also shows a preference for Rb over Sr; the Rb–Sr ratio in montmorillonite ranges from 2 to 10, whereas in analcite the ratio ranges from 0.5 to 10.

The study of the success of formation of the clays and zeolites, by following the stages of conversion of the basalt glass to the final products, reveals a basic difference in mechanism with the zeolite nucleating independently of the previous short-range-order phases to which the clay appears to be more closely related.

ORIGIN OF ASPHALTITE-RICH ORE BODIES AT TEMPLE MOUNTAIN, EMERY COUNTY, UTAH

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Uranium ore bodies at Temple Mountain are composed principally of sandstone impregnated with solid uraniferous carbonaceous substances termed "asphaltite." Most are in petroliferous, sparsely coal-bearing sandstones of the Moss Back member of the Chinle formation, but, near a large pipelike collapse, small bodies are found in petroliferous rocks of other units. The deposits in the Moss Back member are in a belt about 2 miles long and 2000 feet wide, a few thousand feet downdip from the collapse. Within the belt ore bodies are dominantly elongated rolls oriented across the belt; regardless of location most ore bodies have one sharp contact with altered rock nearly devoid of petroleum and one gradational contact with nearly unaltered petroliferous rock. The sharp ore contacts are inferred to mark interfaces formed between carbonated aqueous solutions, introduced through the collapse, and petroleum-rich fluids saturating the sandstones. The introduced solutions displaced oil components from the altered sandstone, and asphaltite, derived from the displaced oil, formed with uraninite and other metallic minerals near stabilized interfaces. Coal extracts may locally have been incorporated in the asphaltite, but judging from the field occurrence the presence of coaly materials was not essential. The cause of precipitation at the interface was probably an increase in pH caused by depletion of carbon dioxide in the introduced solution. This mechanism is suggested principally by epigenetic concentrations of elements which form soluble bicarbonates near the sharp ore contacts.

DIAGENETIC K FELDSPAR IN THE JOHN DAY FORMATION IN NORTH-CENTRAL OREGON

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The lower (Upper Oligocene) member of the John Day formation, 450 feet thick near Mitchell, Oregon, consists largely of massive bentonitic claystones and zeolitized vitric tuffs which are in

accumulation of air-laid rhyolitic to dacitic ash on a hilly land surface. Most of the vitric ash was weathered to montmorillonite at the land surface; unweathered glass was subsequently altered to clinoptilolite. Among the other minerals formed after burial are K feldspar, vermiculite, kaolinite, fluorapatite, quartz, and cristobalite.

The K feldspar is a rather pure one which occurs widely as a pseudomorphous replacement of plagioclase (An_{10-55}), forming barely a trace to as much as a tenth of the claystones. A potassium-argon age of 28.0 m.y. was obtained from authigenic K feldspar in a bed 65 feet above the base of the formation, and ages of 31.3 and 24.4 m.y., respectively, were obtained from pyrogenic materials from beds 165 and 1110 feet above the base. Thus the K feldspar was formed while the John Day formation was accumulating, at a burial depth of perhaps 500 feet. A hydrothermal origin can be eliminated, and the K feldspar probably formed in a low-temperature (15°–25° C.) ground-water environment in which the necessary potassium and silica were supplied by altering ash of the John Day formation. The K^+/H^+ activity ratio inferred for this ground water is significantly lower than recent laboratory experiments seem to demand (*e.g.*, $10^{9.5}$).

DISCOASTERIDS FROM THE SCHLIERENFLYSCH, SWITZERLAND

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The Schlierenflysch of Canton Obwalden, Switzerland, represents one of the most nearly complete sections of upper Cretaceous, Paleocene, and lower Eocene strata exposed in Europe. The sequence of Paleocene and lower Eocene nummulitid faunules is well known. The softer marly layers of the Flysch contain abundant nannofossils, with as many as 100,000 specimens per cubic centimeter. The upper Cretaceous and lower Paleocene strata contain numerous coccolithophorids but no discoasterids. However, study of about 50 samples from the younger portions of the flysch reveals a sequence of discoasterid assemblages closely parallel to that of the species of *Nummulites* and *Assilina*.

Three distinct groups of assemblages may be recognized: (1) The stratigraphically lowest assemblages consist chiefly of a single form, *Discoaster multiradiatus*. The same beds bear *Nummulites deserti* and *N. solitarius* and are referred to the lower part of the Ilerdian stage (middle Paleocene). (2) The next higher assemblages are dominated by *Marthasterites tribrachiatus*, with *Discoaster barbadiensis*, *D. deflandrei*, and small specimens of *D. lodoensis* also present. These occur in beds containing *Nummulites soerenbergensis*, *N. praecursor*, *N. thaliciformis*, *N. rotularius praevius*, *N. atacicus*, *Assilina* aff. *pustulosa*, and *A. leymeriei* and referred to the upper part of the Ilerdian stage (upper Paleocene). (3) The stratigraphically highest assemblages are more varied and contain large specimens of *Discoaster lodoensis* as well as *D. deflandrei*, *D. barbadiensis* and *Zygolithus dubius*. These forms are associated with *Nummulites burdigalensis*, *N. pustulosus*, *N. partschi*, *N. vonderschmitti*, *N. aquitanicus*, *Assilina placentula*, and *A. laxispira*, indicating Cuisian age (early Eocene).

EQUIANGULAR SPIRAL AND THE CLASSIFICATION OF THE ALTICOSTATE VENERICARDS

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Mollusk shells generally grow according to an equiangular (logarithmic) spiral whose polar radii increase according to the ratio $r = e^{\theta \cot \alpha}$ for any values of θ and α and form a constant angle (α) with tangents to the curve at their points of intersection with the radii.

An analysis of patterns of curvature among the alticostate members of the bivalve genus *Venericardia* belonging to the subgenera *Claibornicardia* Stenzel & Krause, 1957, and *Glyptoactis* Stewart, 1930, indicates that members of the former group grew according to a tripartite curve comprising

three distinct spiral angles increasing in value from beak to ventral margin; members of the latter group grew according to a single, or possibly two, spiral angles.

This may indicate that the claibornicards were protandric hermaphrodites which underwent a juvenile asexual stage, followed successively by male and then female adult stages; glyptoactids differentiated the sexes at the beginning of sexual maturity and were not hermaphroditic.

This introduces a new factor into the classification of this stratigraphically important group of mollusks, and evolutionary lineages may be defined on the basis of characteristic growth patterns. The claibornicards appeared in the Cretaceous, surviving until the Miocene; the glyptoactids appeared in the Paleocene and are found in existing seas.

EQUATORIAL ATLANTIC MID-OCEAN CANYON

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Most submarine canyons are furrows cut into the continental margin, but mid-ocean canyons have been found in the abyssal plains. A mid-ocean canyon is a steep-walled, flat-floored, persistent linear depression 1–5 miles wide and a few to more than 100 fathoms deep. Such features have been discovered in the northwest Atlantic east of Newfoundland, south of Nova Scotia, in the Gulf of Alaska, and east of Ceylon in the Bay of Bengal. A new mid-ocean canyon was discovered by the Research Vessel VEMA of Fortaleza, Brazil, and traced for 350 miles. Unlike former mid-ocean canyons which occur in abyssal plains, this equatorial mid-ocean canyon runs southeast along the continental rise and parallels the continental margin. Sounding lines have not revealed any connection between the westernmost end of the canyon and the nearest continental-slope canyon. Cores taken from the floor contained sand and gravel, which indicates that the canyon, if not formed by turbidity currents, at least acted as a channel for them.

The parallelism of the Mid-Ocean Equatorial Canyon with the continental margin on one hand and the mid-oceanic ridge on the other suggests a tectonic control. However, the morphology of the canyon and its sediments suggest an origin through the action of turbidity currents.

SURSASSITE FROM NEW BRUNSWICK, CANADA

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A second occurrence of the rare hydrated manganese-aluminum silicate, sursassite, has been discovered in a Mn-Fe deposit near Woodstock, New Brunswick. The mineral has been found previously only at Va d'Err, Graubünden, Switzerland, occurring in Mn ores in radiolarites of late Jurassic age and associated with partsettensite, errite, and manganoan axinite (tinzenite). In New Brunswick, sursassite occurs in quartzose veinlets cutting a braunite-hematite ore body in complexly folded and faulted Silurian argillites and slates. The vein minerals are quartz, sursassite, braunite, calcite, and barite, in decreasing abundance. Other minerals reported in the associated veins are rhodochrosite, chalcopyrite, galena, and sphalerite; manganoan axinite occurs as disseminated blebs in the ore. The sursassite was previously identified as piedmontite. A new chemical analysis is being made to determine the exact formula, whether Mg is essential, and the nature of the contained water.

NONCONGLOMERATIC ORES OF THE PRONTO URANIUM DEPOSIT

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The uranium deposits of the Blind River Area, Ontario, are widely cited as classic examples of the disseminated U-Th-pyrite mineralization in metaconglomerates. The beds are described as being uniform both in structure and petrology and similar to those of the Witwatersrand. Although this characterizes most of these deposits, it inadequately describes several. Widespread nonconglomeratic ("altered") ores were encountered at the Pronto deposit on the third level in 1956 and have continued through the sixth (bottom) level, at times constituting 40 per cent of the rock mined.

The "altered" rocks include: (1) albitized conglomerates, (2) albitites (some pyritic), (3) chloritic albitites, (4) chloritites, and (5) carbonate rocks (calcitic and dolomitic). Some dolomitic rocks contain pseudomorphs of dolomite after quartz pebbles, together with barite. Locally, vugs contain calcite crystals enclosing sulfides. Sulfides are: pyrite, pyrrhotite, chalcopyrite, galena, and sphalerite. The radioactive minerals include: uraninite and metamict brannerite, both of which may be euhedral, anatase, sphene, globules of hydrocarbon, and several uranyl species.

The nonconglomeratic ores show four types of contacts with conglomerate: (1) faulted, (2) brecciated, (3) gradational, and (4) selective replacement. They flank both sides of a major, west-northwest diabase (3), are confined to areas of faulting, and are faulted and sheared. Within altered ores, uranium values, which are concentrated near footwall contacts, are generally two to four times mine grade. However, ore thicknesses are greatly reduced compared to adjacent conglomerate.

The altered rocks have been formed by replacement of conglomerate and locally of quartzite. The effect of these transformations on uranium distribution has been profound.

LATE PLEISTOCENE ICE CAP CENTERED ON THE NOVA SCOTIAN PENINSULA

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Orientations of striations and of stoss-and-lee topography and the distribution of indicator stones suggest two directions of glacier flow across the northwestern (Bay of Fundy) shore of Nova Scotia.

Palynological correlation and supporting radiocarbon dates indicate that the last continental ice to override northern New England and the Maritime Provinces was a Wisconsin advance predating the Two Creeks interval (11,400–11,900 years B.P.).

In northwestern Nova Scotia, however, the distribution of granite indicators of southern provenance shows that the final glacial movements: (1) advanced from the south; (2) advanced at least 18 miles northward, terminating in the Bay of Fundy; (3) apparently were radial flow from an ice cap centered along the axis of the Nova Scotian Peninsula. Organic material, collected from between two tills on Port Hood Island, has been dated at 10,250 ± 240 years B.P. Therefore, it is suggested, although not substantiated, that local Nova Scotian glaciation postdated the Two Creeks interval.

CALCIFICATION OF SOME CALIFORNIA CRETACEOUS WOOD

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Ignition and X-ray analyses show that dark-brown fragments of *Cupressinoxylon* wood in Cretaceous sandstone from Capay Valley, California, are 92 per cent calcite. Specific gravity of fine

splinters ranges from 2.3 to 2.7. Transverse and tangential thin sections show the original structure well preserved: opaque cell walls, composing about half of the apparent volume of the specimen, enclose fine randomly oriented anhedral calcite grains. The high specific gravity and weight percentage of calcite show that not only the lumina but the cell-wall tissue itself is permineralized.

Excellent, undistorted preservation of cell structure, absence of pyrite, smallness of the calcite grains relative to the cells, and association with marine gastropods suggest that permineralization occurred rapidly—before decomposition or deep burial could weaken and flatten the structure—shortly after deposition in a wide bay or inland sea partly restricted from the open ocean.

COPPER COMPLEXES OF CHLOROPHYLL DERIVATIVES IN THE FORMATION OF PETROLEUM PORPHYRINS

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Petroleum porphyrin pigments are apparently derived from chlorophyll and for the most part contain either vanadium or nickel. Studies of the reactions of clay minerals with chlorin and porphyrin pigments derived from the chlorophyll of the petroleum source material indicate that the introduction of such metals into pigment structures may well take place through copper-pigment intermediate compounds. Pheophytin, pheoporphyrin, phylloerythrin, deoxophylloerythrin, and deoxophylloerythroetioporphyrin were found to abstract copper from illite, kaolinite, and montmorillonite. The abstracting reactions take place much more readily than the corresponding complexing reactions involving vanadium and nickel and require in general no more than a few hours at room temperature. The spectra of the copper complexes are characterized by Soret bands at about 400 mu and two maxima in the range of 510–640 mu. Replacement of the copper in the five pigment complexes by vanadium and nickel was shown to be possible, resulting in the corresponding complexes, the spectra of which, in the case of nickel, were marked by significant shifts to lower wave lengths, and, in the case of vanadium, less significant shifts to higher wave lengths. Both the vanadium and nickel replacement reactions took place under conditions appreciably more severe than those for the corresponding copper complexing reactions.

STRUCTURAL PETROGRAPHY OF A SPECIMEN OF METAQUARTZITE

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Size, elongation, dimensional orientation, neighborhood relations, orientation of optic axis as well as of deformation lamellae, fracture planes, and planes of inclusion are correlated quantitatively for quartz grains in three mutually perpendicular thin sections prepared from the same small (1-inch) specimen of metaquartzite.

The specimen of Early Cambrian age consists of approximately 97 per cent quartz and is markedly foliated. Lineation is not appreciably developed. Most of the larger grains still show a continuous presedimentary coating of iron-oxide dust, have good sphericity, only slight extinction undulosity, and excellent c-axis orientation usually normal to the foliation plane (but in a few cases parallel to it and normal to the macroscopic jointing); the c-axis orientation for the smaller, generally discoidal, and much more deformed grains is highly variable. This is taken to indicate that those grains which during the metamorphic history of the rock remained oriented so that they offered the most resistance to the deforming forces were least affected by intragranular movement, and that the grain size, the dimensional orientation, and the crystallographic orientation are strongly interdependent properties. Formerly continuous planes of inclusion are commonly offset at grain boundaries and appreciably deflected by the extinction undulosity. Deformation lamellae offer a variety of aspects of shape, spacing, character, and intensity of development. Abundant, continuous, and gently curved micro-

lineaments in all three thin sections are produced by the alignment of linear portions of grain boundaries with extinction undulosities. These microlineaments are generally inclined to the trace of the foliation plane.

SOME DATA ON THE SYSTEM $CaCO_3$-$CaCl_2$-CO_2-H_2O AND THEIR IMPLICATION FOR THE PRECIPITATION OF CALCITE FROM HYDROTHERMAL SOLUTIONS

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The solubility of calcite in $CaCl_2$ solutions at 100° C. has been studied as a function of CO_2 pressure and $CaCl_2$ concentration. Solutions between 0.005M and 0.050M in $CaCl_2$ were used in the experiments. The calcium contributed to the solution by the dissolved calcite increases markedly with CO_2 pressure and is nearly independent of the $CaCl_2$ concentration of the solution. The results are in substantial agreement with predictions based on Debye-Hückel limiting-law calculations. The amount of calcite dissolved in these solutions at 100° C. and at a CO_2 pressure of 60 atm. is ca. 1.0 gm/liter and is equal to the maximum amount of calcite that can be deposited from these solutions by CO_2 loss at this temperature and pressure. The amount of calcite precipitated on loss of CO_2 is nearly independent of the total calcium-ion concentration in solution.

The maximum amount of calcite that can be deposited by CO_2 loss from epithermal solutions at 100° C. is probably somewhat greater than 1.0 gm/liter, since the presence of NaCl in solution increases the solubility of calcite. At present it is not certain that loss of CO_2 is the dominant mechanism of calcite deposition from epithermal solutions. If it is the dominant mechanism, the presence of large tonnages of calcite in epithermal ore deposits demands the passage of large, but not impossibly large, volumes of water through the locus of such deposits.

CLASSIFICATION OF SYMMETRY GROUPS

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Point groups and space groups in 3-D are two classes of symmetry groups that have proved most useful in crystallography. Recently other sorts of groups have been described involving a change of "side," sign (antisymmetry), or color; and some of these have already been applied to problems of twinning and magnetic structures. A uniform classification of these various groups should help in visualizing the relations among them and in working out new applications.

If all variables are treated geometrically, including antisymmetry, symmetry groups may be classed according to the dimensions of space that are invariant under their operations. Thus the 80 "antisymmetry groups in a plane" have 2-D and 3-D spaces invariant. The group is "in" the highest-dimensional space of invariance, and translations are allowed only in the lowest-dimensional space. Spaces of intermediate dimensions may also be invariant: the 31 "Streifenornamente" have 1, 2, 3 spaces invariant. Alternatively these classes may be described by the symmetry of the invariant space, using continuous translations and rotations. Thus the class of groups in 2, 3 space are all the crystallographic subgroups of $t\ \infty/mm$, and class 1, 2, 3 are all subgroups of $t\ mmm$.

GEOLOGY OF THE DEMIRKOPRU DAM SITE, SALIHLI, TURKEY

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The Demirkopru Dam constructed near Salihli, Turkey, from 1955 to 1960, dams the Gediz River approximately 80 river miles from the Mediterranean Sea.

A coarsely crystalline gneiss, a portion of the Precambrian Menderes massive, is the country rock.

In late Tertiary time block faulting of the massive formed the Gediz graben through which the Gediz River now flows to the sea. This faulting initiated a new cycle of erosion resulting in the formation of vast alluvial deposits in the area where the river enters the graben valley. These deposits provided a major source of material for the construction of the dam. Quaternary volcanic activity spilled basalt into the valleys adjacent to the dam area. The entrance of these flows into the Gediz River valley dammed the river to form vast lacustrine deposits upstream of the dam site. The rejuvenation of the Gediz River eliminated the lake formed by the basalt dam and developed a new canyon utilized in the present hydraulic scheme. The presence of auxiliary faults resulting from the graben formation or later volcanism influenced tunneling operations, abutment excavation, and powerhouse back-slope treatment. The local rocks at the dam site provided difficult engineering-geology problems relative to the control of leakage.

ORGANIC MATTER IN SEA WATER; AMINO ACIDS, FATTY ACIDS, AND MONOSACCHARIDES FROM HYDROLYSATES

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Hydrolyzed organic material from filtered sea-water samples collected from 10, 500, and 3000 m depths at a single station in the Gulf of Mexico contains a wide spectrum of amino acids and fatty acids and some monosaccharides in which xylose predominates. Isolates of the organic material were made by coprecipitation with iron.

By use of the ion-exchange chromatographic technique, reliable values for the amino acids, aspartic acid, threonine, serine, glutamic acid, glycine, alanine, valine, methionine, isoleucine, leucine, tyrosine, lysine, histidine, tryptophan, arginine, ornithine, and cysteic acid were obtained. These amino acids were present in the surface water in concentrations between 1 and 15 mg/m^3; glutamic acid is most abundant. Tryptophan and lysine were in low concentration. Some differences were observed in both kind and quantity of amino acids with depth.

Fatty acids determined by gas chromatographic techniques showed the presence of C_{12}, C_{14}, C_{16}, and C_{18} acids of both saturated and unsaturated types. Palmitic and palmitoleic acids predominated (15 and 25 per cent, respectively) in the surface waters with a decrease in unsaturation occurring with depth accompanied by an increase in the shorter-chained saturated acids. In the 3000-meter depth, the C_{12} acid was most abundant (42 per cent).

The data show that the predominate components of biological organisms (proteins, fats, and carbohydrates) are distributed vertically in the ocean and appear to be somewhat refractory in nature. A large portion of the organic material present appears to consist of components other than proteins, fats, and polysaccharides. A large portion of these are anion in nature and are thought to fall under the classification of humic acids.

The work reported represents the first successful attempt to isolate and identify and estimate quantitatively the components of proteins, fats, and carbohydrates dissolved in the sea and also show their vertical distribution. These findings may be helpful in pointing the way to better definition of biological as well as geochemical process in the sea, and results of this type may even be useful in studying ocean circulation.

PARACONULARIA? FROM THE MIDDLE CHESTER OF INDIANA

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A 6-foot zone of shales, containing ironstone nodules, at the base of the Golconda formation, SW NE sec. 28, T. 3N., R. 3W., Martin County, Indiana, has yielded about 50 specimens of *Paraconularia? chesterensis* (Worthen). This species also occurs in calcareous shales of the Glen Dean

formation in Crawford County, Indiana. External ornamentation indicates that the species belongs in Paraconulariinae, but lack of sharply inflected ribs at corner furrows and lack of ornamentation in rib interspaces make placement in *Paraconularia* suspect. Specimens are associated with a normal marine Chester brachiopod and bryozoan fauna. Examination of the holotype shows no difference between it and the writers' specimens. Because the specimens are incomplete quantitative studies have not been successful. Plot of number of ribs in 5 mm versus width of side where measured does not yield consistent results. X-ray-diffraction data indicate that the shell is composed of apatite.

Brief description: neither apertural nor apical ends preserved; transverse ribs interrupted at corner furrows, very slightly bent aperturally; ribs both interrupted and continuous across midline; no internal structures observed; no ornamentation on ribs; in some specimens irregular bars in interspaces near corner furrows; in a few specimens horizontal bars in interspaces at midline as a result of "feathering" of ribs at midline; apical angle about 5°; specimens exhibit both square and rectangular cross sections; preserved portions up to 15 cm long and 3.5 cm wide; ribs commonly 1–2 mm apart, closest spacing at base. Variation in spacing suggestive of periodic changes in growth rate was not observed.

FOSSILS FROM THE RED BEDS OF THE BLOOMSBURG FORMATION OF CENTRAL PENNSYLVANIA

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The Silurian Bloomsburg formation is composed of grayish-red clay stone, siltstone, and clayey very fine- to coarse-grained sandstone. A few beds of conglomerate are found in the region of maximum thickness of the formation. Minor amounts of grayish and greenish clay stones are present in interbeds.

The Bloomsburg red beds extend from eastern Pennsylvania west and southwest along the belt of the Folded Appalachians into Maryland, Virginia, and West Virginia. Traced from the area of maximum thickness (about 2000 feet) in the Delaware Water Gap region, the formation thins to nearly 400 feet in central Pennsylvania and to extinction in Virginia and West Virginia. In central Pennsylvania the red beds interfinger with part of the marine clay stones and limestones of the overlying and underlying formations.

The red beds are fossiliferous throughout much of central Pennsylvania. The Bloomsburg fauna consists of Foraminifera, coelenterates, brachiopods, mollusks, ostracods, crinoids, and heterostracid scales. All these groups are rare except for the brachiopods and ostracods, and only the ostracods are well preserved. Of the 25 ostracod species described, 3 are restricted to the red beds, the remainder are found in red beds and nonred clay stone and limestone.

The Bloomsburg fossils indicate that their enclosing red beds were deposited subaqueously in brackish water and that the red color of the sediments is primary and not postdepositional in origin. The fauna also shows that the Bloomsburg formation of central Pennsylvania is predominantly equivalent to the marine limestones of the McKenzie formation.

STRUCTURAL DEVELOPMENT OF THE WILLIAMS RANGE THRUST, COLORADO

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Field study has been made of an area including the central part of the Williams Range thrust trace, which crops out on the west side of the Williams Fork Mountains and on the west side of Middle Park, Colorado, in the south-central Rocky Mountains.

Observation of a cross section of the thrust surface and other data on the fault trace and on minor structures associated with the trace (*e.g.*, west dips of sedimentary rocks in the overblock) show that

the thrust surface is curved; it is nearly horizontal in westernmost exposures and progressively steeper with eastward dips to the east. Synclines parallel the thrust on both the east and the west, and a major high-angle fault lies east of the former syncline.

The structure as mapped and deformation observed in available model experiments for a stress system characterized by a vertical-step displacement of the lower boundary of a body agree in all major respects. Reconstructed stress trajectories of an average east-west cross section and those for a vertical-step stress system are virtually coincident; this system predicts fault development at locations where faulting has developed in the mapped area.

Requirements for such a stress system are both compatible with the regional structural geology and geologically practicable. On the basis of the uniqueness theorem of elasticity theory, the writer believes that an explanation very much different from the vertical-step system cannot explain the structural development.

FACTORS INFLUENCING THICKNESS OF THE EARTH'S CRUST

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J. F. Lovering (1958) and others have suggested that the thickness of the earth's crust depends on the temperature gradient. If this hypothesis is correct, then, if other factors are the same, it should depend also on surface temperature. For every °C. increase in surface temperature, Lovering's figures indicate that the crust should be 0.08 km thicker. Twenty-one published figures of crustal thickness of the continents indicate that the variation of thickness with mean annual surface temperature is $H = 31.3 \text{ km} + 0.009T \text{ km/°C}$.

The relation between thickness and surface elevation, using the same data, is $H = 30.2 \text{ km} + 0.00155h$ km/meter. The relation of thickness to distance from the nearest edge of the continents is $H = 29.2 \text{ km} + 0.0033 X$ km/km.

The data are so scattered that it is difficult to choose which of the three relationships is the best. This is not surprising, since the three variables are not independent. The dependence on surface temperature appears to be the least significant. An accuracy of ± 1 km or better for crustal-thickness measurements should be the goal of such studies if correlations such as these are to be studied.

INTERDEPENDENCE OF THE COMPOSITION OF HEAVY-MINERAL ASSEMBLAGES WITH THE GROSS COMPOSITION AND TEXTURE OF SANDSTONES

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The mineralogical "maturity" of the heavy-mineral assemblages of sandstones is quantitatively defined by a proposed zircon-tourmaline-rutile (ZTR) index. The ZTR index is the percentage of the combined zircon, tourmaline, and rutile grains among the nonopaque, nonmicaceous, detrital heavy minerals. In most arkoses and graywackes, the average ZTR index is low but varies widely among samples; apparently local lithologic source-area variations largely control these relatively unmodified heavy-mineral assemblages. In transitional feldspathic and micaceous quartzose sandstones derived by selective sorting and abrasion from arkosic and micaceous (graywacke) detritus, a parallel increase occurs in both the average ZTR index and the percentage of quartz plus chert among the grains (clayey matrix omitted). The ZTR index is more than 90 per cent in most orthoquartzite sandstones. As the ZTR index increases, a concentration of the varieties occurs, based on color, inclusions, and form of tourmaline, zircon, and rutile, together with a decrease in the number of nonopaque heavy minerals.

The ZTR index was applied to the Permian littoral Lyons sandstones (Colorado Front Range), which average a feldspathic quartzite composition and were derived from arkosic detritus from the

ancestral Front Range. The Lyons ZTR index ($\bar{x}$ = 75 per cent) increases as the proportions of quartz increase and feldspar decrease in the detrital fraction, and as the nonaggregate quartz grains become smaller and better sorted.

Tectonism not only largely controls the gross mineralogy and texture of sandstones but also determines the composition of the heavy-mineral assemblages. Intrastratal solution of heavy minerals is not generally volumetrically important.

COMPARISON OF ANALYTICAL METHODS USED IN GEOCHEMICAL PROSPECTING FOR COPPER

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Analytical methods used in geochemical prospecting for copper were compared by repeated analysis of samples of residual soil collected near a copper-bearing vein at the Malachite mine, Jefferson County, Colorado. In this area "barren" samples (of only background copper content) have a mean copper content of 58 ppm, and samples anomalously high in copper have a mean copper content of 216 ppm. Mean copper contents of most anomalous samples are more than 100 ppm and of most barren samples less.

Rapid or semiquantitative methods, such as the spectrographic, biquinoline, dithizone, and chromograph tests for copper and the citrate-soluble and acid-soluble tests for total heavy metal, are almost as sensitive but are less precise and less accurate than standard quantitative trace-analysis methods. Statistical techniques based chiefly on the coefficient of variation show that the field methods differ considerably among themselves in sensitivity, precision, and accuracy. This study indicates that the dithizone and the biquinoline tests for copper are the best for geochemical prospecting in this area.

TIME OF INTRUSION OF THE PURCELL SILLS, SOUTHEASTERN BRITISH COLUMBIA

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Biotite samples from two thin Purcell sills of southeastern British Columbia give A^{40}/K^{40} ages of 558, 578, 669, 835 million years. Values of 558 and 578 million years were determined for the biotite hornfels developed at the lower contact of the Moyie "A" sill (Daly, 1912) at Kingsgate, on the international boundary.

The other sill, exposed on the Cranbrook-Kingsgate highway, about 20 miles north of the Moyie occurrence, provided biotites from two distinct and different mineral assemblages. Coarse-grained biotite, separated from a narrow quartz-biotite vein is dated at 669 million years. An age of 835 million years was obtained using fine-grained biotite from the diorite at the base of this sill. The latter date may indicate the time of intrusion of the Purcell sills. Dates from the metamorphic biotites at the contacts of the Moyie sill appear to be too low, but they represent a minimum age for these intrusives.

The age-dating decay constants are:

$$\lambda\rho = 0.589 \times 10^{10}/\text{yr.}$$

$$\lambda\beta = 4.76 \times 10^{10}/\text{yr.}$$

LONGITUDINAL FILLING IN THE ALEUTIAN TRENCH

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The Aleutian Trench east of long. 180° has a flat floor. This long slender abyssal plain is 2–18 miles wide, varying inversely with the longitudinal slope. The long profile of the trench is smoothly graded but shows nickpoints where the trench is constricted at the intersection of two volcano-crested rises. West of 169° W., the trench floor has no longitudinal slope indicating ponded sediment in the central part of the trench.

Several echograms in the widest part of the trench show a narrow channel at the base of the landward slope. The location of this channel, as well as ubiquitous evidence of a gentle slope of the trench floor toward the north, suggest the effect of active tectonism.

The sources of sediment extend east as far as Baranof Island in southeastern Alaska. This sediment has produced fans at the base of the continental slope and a channeled abyssal plain sloping westward into the trench.

Very sparse data west of long. 180° suggest a flat eastward-sloping trench floor in this region.

NEW EVIDENCE ON THE NORTHWARD CONTINUATION OF THE SAN ANDREAS FAULT

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Recent soundings indicate that the submarine topography between the Mendocino Escarpment and Queen Charlotte Sound out to 300 miles from land is characterized by two intersecting systems of ridges. These ridges trend approximately north-northeast and west-northwest. In this pattern of ridges north of the Mendocino Escarpment, two large and very prominent northwesterly trending ridges are found.

The southern, and longest, ridge begins 40 miles from the coast at about 42° 30′ N. where it has only 250 fathoms of relief above the adjacent abyssal plain. Farther from land it curves south from northwest to west-northwest, and becomes higher; relief near 130° W. is 1500 fathoms. The northern ridge becomes evident about 120 miles from land but reaches similar elevations near 130° W. A trough between these ridges is largely filled with sediment from the Cascadia abyssal plain. Part of the trough acts as a pass through which Cascadia channel flows to the plains farther west. The northwestern part of the trough, isolated from turbidity currents, reaches depths of about 2400 fathoms, 700 fathoms below the regional depths of the area.

Epicenters in this region appear to fall into three distinct lobes. One, about 120 miles long following the Gorda Escarpment, and a second, 200 miles long, at the base of the continental slope, may represent displacement on older lines of weakness. The third, about 360 miles long, closely approximates the two major west-northwest-trending ridges and appears to be the most likely continuation of the San Andreas fault beneath the sea.

TIME-SPACE RELATIONS ALONG SOUTHWEST FLANK OF PIKES PEAK BATHOLITH AND ITS METAMORPHIC WALL ROCKS, PARK AND TELLER COUNTIES, COLORADO

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The rock sequence on the southwest flank of Pikes Peak batholith is, from oldest to youngest: (1) great thickness of biotite-quartz-feldspar augen gneiss, (2) Cripple Creek granite, and (3) Pikes

Peak granite. This chronology is based on visible field relations and differs from earlier, erroneous interpretations.

Throughout a 25-mile distance and at the four localities, Pikes Peak batholith contact discordantly cuts flow structures and xenolithic inclusions in Cripple Creek granite at angles of 40°–90°. Linear structures in Pikes Peak granite plunge 60°–88° in a S. 70° W. average direction, and those in Cripple Creek granite plunge 50°–85° in a N. 85°–35° W. direction.

Pikes Peak granite does not grade into augen gneiss through a zone of shearing or porphyroblastesis. Linear structures in the two rocks commonly are approximately at right angles. Augen structure in the gneiss decreases in grain size toward its contact with Pikes Peak granite. Grain size of the granite decreases in most places from coarse to medium toward its contact with the gneiss. Cripple Creek granite is intruded along foliation planes of the augen gneiss.

The augen gneiss has been mistaken for (erroneously assigned to) Pikes Peak granite. What might be called typical Pikes Peak granite has K^{40}/A^{40} ages of 1.030–1.040 billion years, whereas augen gneiss, where dated so far, is 1.450 billion years old.

The revised sequence leads to a better understanding of late Precambrian tectonics. It also demands that pegmatites and aplites in the metamorphic wall rocks be identified as either older than Pikes Peak granite or cogenetic with Pikes Peak granite.

PRELIMINARY REPORT ON THE SYSTEM ENSTATITE-ANORTHITE-DIOPSIDE

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The join enstatite-anorthite-diopside was investigated using the method of quenching at 1-atm. pressure. Optical and X-ray methods were used to identify the solid phases encountered at various temperatures between 1050° C. and the liquidus temperatures. The join cuts the primary phase volumes of forsterite, anorthite, and diopsidic pyroxene at liquidus temperatures. The minimum liquidus temperature (1262° ± 5° C.) is at a piercing point; its composition in weight per cent is 16.5 enstatite, 43.5 anorthite, and 40 diopside. The equilibrium diagram for the join with isotherms is presented.

The complex relations at temperatures below the liquidus temperatures are presented with the aid of isothermal planes. Three polymorphic modifications of $MgSiO_3$ (protoenstatite, clinoenstatite, and orthoenstatite) each as solid solutions appear at various temperatures during crystallization or appear as quenching products. Small amounts of free silica (present as cristobalite, metastably) were observed in some of the compositions rich in diopside. This is a consequence of the presence of Al_2O_3 in the pyroxenes which are not binary $MgSiO_3$–$CaMgSi_2O_6$ pyroxenes. At appropriate temperatures and compositions two pyroxenes ($MgSiO_3$-rich and diopsidic pyroxenes) coexist with liquid or with liquid and forsterite.

The join enstatite-anorthite-diopside roughly bisects the tetrahedron representing the system forsterite-anorthite-diopside-silica.

USE OF INDEX PROPERTY VALUES OF SURFICIAL MATERIALS

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The foundation engineer, in summarizing and correlating his experiences with whatever material he encounters, has devised certain physical tests to give numerical results, known as index properties, as a means of distinguishing different kinds of soil. These classification tests have been chosen so that materials having similar index properties are likely to exhibit similar engineering behavior.

The geologist who deals with surficial deposits may find the procedures of the engineer extremely useful for correlation studies and in distinguishing deposits. For instance, the position of the Atter-

berg limits for the liquid and plastic states on the plasticity chart developed by A. Casagrande may indicate whether a given material behaves as a clay or as a silt and may enable the geologist to distinguish readily between two samples that otherwise appear similar. The grain properties, natural water content, unconfined compressive strength, sensitivity, activity, void ratio, and penetration resistance are also used to identify and to distinguish between different materials.

STRATIGRAPHIC VARIATION OF CHROMITE COMPOSITION WITHIN CHROMITITE ZONES OF THE STILLWATER COMPLEX, MONTANA

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Cleaned chromite from 40 channel samples taken from two chromitite zones in the Stillwater complex were chemically and spectrographically analyzed. The stratigraphically lower of the two zones, called the "G" zone, is 12 feet thick and consists of alternating layers of chromitite, olivine chromitite, and poikilitic chromite harzburgite. The stratigraphically higher zone, called the "H" zone, is 17 feet thick and consists of a lower section of chromitite and olivine chromitite and an upper section of poikilitic chromite harzburgite separated from the lower section by an 11-foot-thick layer of harzburgite that contains virtually no chromite. Preliminary examination of the analyses shows that a greater variation in chromite composition exists within the two zones than exists between comparable layers in the remaining 10–12 recognized chromitite zones of the complex. Within both zones the amounts of Cr_2O_3 and MgO in the pure chromite decrease upward in the section, Fe_2O_3 and FeO increase upward, and Al_2O_3 has no regular or consistent stratigraphic variation. Of the minor elements, TiO_2 and MnO increase with FeO; V_2O_3 and Ga_2O_3 increase with Fe_2O_3; and CoO, NiO, and CuO seem to have no consistent variation. Compositional changes are related not only to stratigraphic position in the zones but also to the relative amounts of chromite and olivine in any particular layer; in layers where chromite is not abundant it tends to be richer in Fe_2O_3 and FeO and poorer in Cr_2O_3 and MgO than in contiguous massive chromite layers.

AGE OF THE *TRICERATOPS* BEDS AND COMPARABLE DINOSAUR-BEARING BEDS OUTSIDE NORTH AMERICA*

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The *Triceratops* beds of the western interior of North America are of Maestrichtian—not Danian—age because: (1) The Hell Creek (= Lance) formation overlies conformably and gradationally upper lower Maestrichtian beds of the type Fox Hills sandstone; (2) The Hell Creek (= Lance) beds with typical nonmarine mollusks and dinosaurs of *Triceratops* zone replace laterally the marine and brackish-water members of the type Fox Hills sandstone; (3) *Scaphites* is associated with *Triceratops* fauna in the upper part of the Lance formation (W. Clemens, personal communication); (4) Planktonic foraminifers indicate the Danian age of the Cannonball formation (Dr. N. Brown, Jr., personal communication).

The Cretaceous/Tertiary boundary in western North America is placed between the Hell Creek (= Lance) formation and the Fort Union group by all modern workers. This boundary coincides, however, with the Maestrichtian/Danian and not—as hitherto assumed—with the Danian/Landenian boundary.

Nowhere are there any known, or even probable, dinosaur occurrences in beds of post-Maestrichtian age. All youngest dinosaur-bearing beds outside North America (*e.g.*, in southern Europe,

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Patagonia, and Mongolia) claimed to be Danian are demonstrably Maestrichtian or older. As far as is known, dinosaurs had, thus, disappeared globally prior to the end of the Maestrichtian. Their disappearance coincides, therefore, with that of many other typically Mesozoic groups of animals (*e.g.*, ammonites, true belemnites (Belemnitellidae), rudists, Cretaceous planktonic foraminifers, marine and flying reptiles). Instead of favoring the Cretaceous placement of the Danian stage the dinosaurs provide another argument in favor of its assignment to the Tertiary.

GEOLOGY AND ORE DEPOSITS OF THE MATTAGAMI AREA, QUEBEC, CANADA

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The Mattagami area comprises about 750 square miles approximately 120 miles northeast of Noranda, Quebec. Less than 5 per cent of the surface area is outcrop, and glacial overburden averages about 75 feet with depths of 200 feet in places.

Although the area has been prospected by conventional methods since 1928, the original ore deposit was located by an air-borne magnetic and electromagnetic survey followed by similar work on the ground.

The zinc-copper ores of the area are irregular replacement deposits in a series of typical Keewatin lavas, tuffs, and fragmentals. In general, the mineralized zone appears to extend around the west, northwest, and north sides of an area of basic intrusives known as the Bell River complex. Lineal extent of this mineralized zone is about 25 miles.

The lava-tuff series dips moderately to steeply away from the central basic complex, and ore deposits have been found on minor anticlinal flexures adjacent to a key tuff zone in the series.

At the end of 1959, published ore reserves for the area were 30 million tons, averaging 12 per cent zinc, 0.75 per cent copper, 0.02 oz. gold, and 1.25 oz. silver. Additional ore is being added to this total by extensive diamond drilling. Ultimate potential of Mattagami is still unknown.

BIOGEOCHEMISTRY OF SULFUR ISOTOPES

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Through a combination of economic and sulfur isotopic geology, evidence has been obtained that anerobic bacteria have played important roles in the formation of native sulfur deposits, "redbeds" copper deposits, and sandstone-type uranium deposits.

The factors of anerobic viability, production rates of H_2S, and the extent of isotopic fractionation of sulfur reduced from $SO_4^=$ to H_2S have been studied by laboratory experiments with raw culture cells containing Long Island Sound mud (with anerobes) and sea water that approximate natural conditions.

Fractionation greater than 8 per cent of sulfur isotopes should be evident by unidirectional reduction of $SO_4^=$ to H_2S. Yet, both pure and raw-culture laboratory experiments rarely indicate isotopic fractionation greater than 2 per cent. However, by varying the amounts of nutrient, mud, sea water, and soluble sulfates in the cells, the rate of reduction and extent of isotopic fractionation may be varied.

Anerobes in a raw-culture cell containing 80 gms of mud, 450 ml of sea water, and 2 ml of sodium lactate (nutrient) solution have reduced more than 88 per cent of the available sulfate during a period of 5 days with an S^{32}/S^{34} ratio decrease of the $SO_4^=$ from 21.77 to 21.46. In similar cells to which no nutrient was added, less than 12 per cent of the sulfate was reduced during a 2-month period, and the S^{32}/S^{34} ratio changed from the original of 21.77 to only 21.62.

These and similar fresh-water-mud studies may permit recognition of continental versus marine formations from enclosed syngenetic sulfides.

PAMELIA EAST OF THE FRONTENAC AXIS IN NEW YORK STATE

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The Pamelia formation, basal unit of the Black River group (Lower Mohawkian), until now has never been reported east of the Frontenac axis in New York State. Its presence in the upper Champlain Valley was established as a result of intensive field studies to define the geologic characteristics of rocks in State-approved quarries for the New York State Department of Public Works.

The rock sequence assigned to the Pamelia has been recently exposed in a quarry situated 1 mile southeast of the village of Chazy, Clinton County. Here 3 feet 8 inches of faintly green, medium-gray (N5) dolomosiltite containing abundant rounded quartz grains of sand size and a few thin interbeds of greenish-gray (5G6/1) dolomitic shale with fucoidal markings lies directly on top of *Rostricellula*-bearing, medium dark-gray (N4) calcisiltites and calcarenites of the Valcour formation (Upper Chazyan). The Pamelia is succeeded by typical *Phytopsis*-bearing, medium dark-gray calcilutites ("birdseye" limestone) of the Lowville formation.

The Pamelia in the upper Champlain Valley occupies a proper stratigraphic position. It is nearly identical to lower Pamelia east of the Frontenac axis in Canada, and it is lithologically similar to the arenaceous basal beds of the type Pamelia west of the Frontenac axis in Jefferson County, New York.

COMPARISON OF CORE ANALYSIS AND DRAWDOWN TEST RESULTS FROM A WATER-BEARING UPPER PENNSYLVANIAN SANDSTONE OF CENTRAL OKLAHOMA

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Laboratory measurements of cores are a common and often the only method of obtaining a permeability value necessary for predicting reservoir performance. Permeability from core analysis is usually considered unrealistic and not representative, at least quantitatively, of reservoir conditions.

Permeability of horizontal plugs cut from each foot of 65 cores from an 8-acre area was measured with a constant-head discharging apparatus using reservoir water. The field coefficient of transmissibility was computed by applying the Theis type-curve solution of the nonequilibrium formula to drawdown data from 64 wells surrounding a single discharging well. The two methods of permeability measurement show quantitative agreement.

PENNSYLVANIAN LIFE ASSEMBLAGES, WESTERN ILLINOIS

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Statistical study of 63 species of Pennsylvanian invertebrates in 152 collections from western Illinois provides basis for recognizing recurrent and concurrent species associations. Recurrent association is defined as the relation between two species that occur together more commonly than apart. Concurrent association is defined as the relation between two species whose distributions are not independent, as shown by an X^2 test. Positive concurrent association at the 0.005 level of significance

was used to form 19 groups of associated species. The stratigraphic, lithologic, and biologic characteristics of these groups were used to infer life assemblages. The most distinctive of these assemblages were associated with the upper limestone or black-shale members of cyclothems. The method is applied to data from modern communities, and results indicate that these Pennsylvanian associations can be interpreted in ecologic terms with special reference to substrata and depth of water or distance from shore.

TEACHING GEOLOGY BY TELEVISION—AN EFFECTIVE METHOD OR A GIMMICK?

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The use of television as a means of teaching geology is becoming increasingly prevalent, especially at the first-year level. The advantages of television presentation of lecture material include: use of a wide variety of visual aids; replacement of a single large lecture room with multiple small-capacity rooms; improved staff and space utilization; improved lecturing as a result of compulsory preparation. Disadvantages include: absence of student-teacher contact; objection by students to the use of television instruction.

An attempt is made to overcome the disadvantages by: having the lecturer share in laboratory and field-trip instruction; maintaining a conversational approach during at least a part of a televised lesson; answering questions individually during laboratory sessions or by means of talk-back circuits to the studio; providing an orientation lecture during which the various teaching methods and aids to be used are joined together in a subtle selling program.

Testing by television has been used in a limited way and is a fruitful area for continued experimentation in both lectures and laboratories. Testing appears to be limited to visual material such as maps, air photographs, photographic slides, and specimens that are identifiable by form. Television use is not proposed as a substitute teaching or testing program for those which are adequate. Its use is justifiable only where advantages gained from improved material presentation or solution of scheduling problems outweigh the advantages of normal classroom instruction.

DEPOSITIONAL ENVIRONMENT OF THE COAL-BEARING FORMATIONS OF THE RATON MESA COAL REGION, NEW MEXICO AND COLORADO

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The Raton Mesa coal region includes 2500 square miles in northern New Mexico and southern Colorado. Coal-bearing units are the Vermejo formation of Late Cretaceous age and the Raton formation of Late Cretaceous and Paleocene age. These formations consist of complexly interbedded sandstone, siltstone, mudstone, and coal; the base of the Raton is marked by thin conglomerate beds. The Raton is overlain locally by the noncoal-bearing Poison Canyon formation, which is composed mainly of arkosic conglomerate and sandstone and thin mudstone beds.

Contact relations between the formations are gradational in the central part of the region; however, in the north an erosion surface at the base of the Poison Canyon cuts out the underlying Raton and Vermejo formations. In the south in Colorado, lower beds of the Poison Canyon grade laterally into upper beds of the Raton in a southwesterly direction. To the southwest in New Mexico, the Poison Canyon formation completely replaces the Raton, and the lowest beds of the Poison Canyon are age equivalents of the basal conglomerate of the Raton formation in the northern part of the region.

Sediments were derived from Precambrian terranes west and north of the region. The Vermejo formation was deposited on a narrow low and swampy coastal plain that lay between a slowly rising

epeirogenic uplift to the west and the retreating Late Cretaceous sea to the east. During Raton and Poison Canyon deposition the area was a slowly subsiding nonmarine basin near the eastern margin of the rapidly rising Laramide Rocky Mountains.

OSTRACODA FROM THE CENTRAL ARCTIC BASIN

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Bottom samples and cores taken from the floor of the Central Arctic Basin by the U. S. Air Force in 1952–1955 have yielded a numerically sparse but quite varied fauna of ostracodes. Genera represented include *Argilloecia*, *Basslerites*, *Cytheropteron*, *Echinocythereis*, *Krithe*, *Monoceratina*, *Pellucistoma*, and *Xestoleberis*. Sixteen species are present, including two new forms. Some forms reported show evidence of stratigraphic and geographic displacement.

The most noteworthy characteristics of the fauna are the thin carapaces, extreme development of spines and other ornamentation in such forms as species of *Cytheropteron* and *Monoceratina*, and absence of instars of some species.

EXPERIMENTAL STUDY ON THE MECHANICS OF BEDDING

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A quasi-quantitative, hydraulic investigation of the origin of various types of cross-bedding was undertaken utilizing sands of diverse textural composition in a laboratory flume.

A crude empirical method was formulated for quantifying the expanding flow pattern over a delta front, and this basic hydraulic geometry was exploited in predicting downstream particle loci and the distribution of grain sizes in the bottomsets. The distribution and dispersion of the clastic elements in foresets, toesets, and bottomsets of an ancient deposit may provide a useful index in environmental reconstruction.

The study demonstrates, contrary to preconceived ideas, that a low-velocity regime favors the development of the angular (basal-contact) type of deltaic unit (microslip cross-bedding). High-velocity, sediment-laden flow is conducive not only to the establishment of a strong tangential contact (toesets), but also to a substantial reduction in foreset dip angle (turbidite cross-bedding). The investigation also demonstrates that well-defined topset and foreset lamination may develop under constant-flow and sediment-discharge conditions.

The phenomenon of flow separation is the earmark of cross-bedded deposition. Genetically, the structure may be subdivided into cross-bedding of form-drag origin (ripples, dunes), aggradational (deltaic) origin, and polygenetic origin (offshore bars, point bars).

PALEOZOIC ROCKS OF THE JACK CREEK MOUNTAINS, NORTHERN INDEPENDENCE RANGE, ELKO COUNTY, NEVADA

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The northernmost flank of the Independence Range, along Jack Creek and the upper North Fork of the Humboldt River in northern Elko County, Nevada, has a sequence of Carboniferous cherts, turbidites, quartzites, and volcanic rocks described by J. J. Fagan. The stratigraphy and structure of the thrust sheets in the Seetoya Mountains east of Tuscarora have been studied by J. W. Kerr. The intervening highest part of the range, the Jack Creek Mountains culminating in McAfee Peak (10,439 feet), is of quartzite and interbedded radiolarian chert overlying graptolite-bearing Ordo-

vician argillite; the sequence may stratigraphically underlie the Carboniferous rocks to the northwest. The lower canyon of North Fork, northeast of the mountains, is within a triangular fault block which has the Carboniferous cherty sequence on the northwest and the high-range quartzites and cherts to the south of Peterson Creek and to the east of the range border fault. Within this block, several thousand feet of Carboniferous quartz sandstones and impure limestones contrasts with the sequence on the northwest. A basal quartzite-pebble conglomerate lies with angular unconformity on upper Cambrian laminated argillaceous calcisiltites with siliceous interbeds. This triangular block is autochthonous with respect to the rocks that surround it. Southeastward of the high range, the allochthonous rocks have cherts and pillow lavas. The thrust plane separating the allochthonous eugeosynclinal and the autochthonous miogeosynclinal sequences is post-Carboniferous and presumably is that exposed in the Seetoya Mountains.

MAGNITUDE OF CRUSTAL MOVEMENT AND DEPOSITION DURING LATEST CRETACEOUS AND EARLY TERTIARY TIME IN THE WIND RIVER BASIN, CENTRAL WYOMING

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Extensive crustal mobility characterized the Wind River Basin during the major phases of the Laramide orogeny in latest Cretaceous and early Tertiary times. The stratigraphic and structural relations of sedimentary rocks more than 15,000 feet thick that accumulated in the region during this period record significant changes in environments of deposition brought about by considerable shifting of major troughs of deposition, progressive growth of anticlines, rapid uplift of adjacent mountains, and pronounced sinking of local basin areas.

Latest Cretaceous and early Paleocene time was a period of incipient folding in the basin and broad domal uplift of some parts of the adjacent mountains. Clastic debris was deposited on flood plains of rivers flowing southeastward across the basin. During middle and late Paleocene time the central and eastern parts of the basin were inundated by an extensive body of water which transgressed from the east or northeast. Two thousand feet or more of black shale was deposited.

The major orogenic movements, featured in some places by rapid uplift along extensive reverse faults, took place at the close of Paleocene time and during successive stages of early Eocene time. Displacement locally exceeded 30,000 feet. A broad north-trending structural platform formed across the central part of the basin, dividing the region into two deep troughs. Eocene strata are 3000–4000 feet thick on the platform but are locally more than 9000 feet thick in the adjacent troughs.

CARBON AND OXYGEN ISOTOPE RATIOS IN MARINE AND FRESH-WATER MOLLUSK SHELLS

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Results are given of a systematic survey of differences in the isotopic composition of carbon and oxygen of modern mollusk shells from marine and continental environments. Marine shells analyzed show a range of δ C^{13} (relative to Chicago PDB standard) from +4.3 to −1.7‰, whereas the fresh-water mollusk shells have consistently lighter carbon, in the range δ C^{13} = −2.4 to −13.6‰. There is a similar difference in O^{18} content. Strictly marine samples fall in the range δ O^{18} = +3.0 to −3.0‰, whereas the fresh-water samples fall in the range δ O^{18} = −6.5 to −8.9‰.

Within the marine group, environmental subgroups differ mainly in O^{18} content, and the differences are consistent with the temperature dependence previously studied by other investigators.

Within the fresh-water group, the most striking difference between subgroups is in the C^{13} content of mollusks living in lakes ($\delta\ C^{13} = -2.4$ to $-6.0‰$) and those living in rivers ($\delta\ C^{13} = -11.0$ to $-13.6‰$). Controlling factors are evaluated, and it is concluded that the carbon isotope ratio in mollusk shells is considerably influenced by the proportional amount of isotopically light land-plant carbon included in the food of the mollusks or contributed by humus decay to the dissolved CO_2 in the water. It appears likely that the observed isotopic differences, particularly the differences in C^{13} abundance in carbonates, can be applied to the environmental study of sedimentary rocks and will provide an additional tool for studies of paleogeography.

STRUCTURE BEHIND THE BANNOCK THRUST, IDAHO

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The Bannock thrust is the westernmost of several arcuate, west-dipping thrusts in southeastern Idaho and western Wyoming. It forms the east boundary of a Laramian? north-trending horst on the cratonal side of the Paleozoic miogeosyncline. West of the thrust near Paris, Idaho, lie a broad north-trending syncline (Bear River Range) and a slightly folded, northeast-dipping homocline (Port Neuf Range). Normal faults, downthrown to the west, and transverse and thrust faults cut the ranges.

Wasatch? conglomerate and up to 10,000 feet of Mio-Pliocene Salt Lake group overlie Laramian? folds and faults. At Treasureton basal Salt Lake conglomerate lies with little discordance on Precambrian, Cambrian, and Ordovician in adjoining blocks, indicating block-faulted terrain in pre-Salt Lake time. Post-Salt Lake folding, faulting, and tilting to overturning reveal an important Pliocene disturbance.

Rubey and Hubbert, citing examples for their geosynclinal slide theory (restricted), inferred a broad linear gap behind the Bannock thrust. The only exposures suggesting such a gap are at Treasureton, a range junction, where Precambrian (3 square miles) and lower Paleozoic chaos are found. A larger block of Precambrian-Cambrian quartzite, discontinuous north and south, is upthrown westward in Oxford Mountain and unexplored. Their theory does not explain the interval between deposition (more than 28,000 feet) of Precambrian-Paleozoic rocks and Laramian? thrusting. The complexity of the Bannock thrust zone, with no windows or apparent sole planes behind it, suggests that the thrust steepens west of Paris. Present evidence favors the interpretation of block uplift associated with peripheral thrusting.

BERNOULLI'S LAW APPLIED TO HARBOR ENTRANCES AND BRIDGES

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This paper undertakes to show that Bernoulli's theorom and Venturi's principle are really one natural law operating in the formation and control of natural harbor entrances and river channels. Bernoulli's principle is: increasing the velocity of a gas or a liquid brings an accompanying decrease in pressure. Venturi later discovered that narrowing the cross-sectional area of a tube increased the velocity through the narrowed section and decreased the pressure on the walls of the narrowed section. This discovery led to the development of the Venturi flow meter, the airplane cambered wing, and other mechanical devices. The Bernoulli-Venturi principle has not generally been considered as a natural law because its operation in nature has escaped notice.

Aerial photographs of Mission Bay, California, taken in 1917, compared with parallel rock jetties recently constructed at the same location, show that the natural Venturi entrance remained open, whereas the new parallel jetty entrance "sanded up" within a few months.

A working scale model of the Agua Hedionda Lagoon at Carlsbad, California, proved: (1) that

straight channels cut through a sand bar will, in a few seconds, erode into Venturi-shaped channels and remain so; (2) that a bridge or harbor channel with parallel sides reduces the water velocity, causing sanding, whereas curving sides of Venturi shape increase the velocity and scour the channel clean.

Cost comparisons show that the Venturi entrance is much less costly to build than the parallel rock jetty type.

ROCK WEATHERING IN THE ANTARCTIC

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A series of progressively weathered specimens from a fine-grained quartz diorite outcrop at Marble Point, McMurdo Sound, in the Antarctic, were studied because they appeared to have undergone extensive chemical weathering beyond that expected in a region of such extreme cold and aridity. The light-gray, well-knit rock weathers to a rich brown sand with particles as small as .003 mm.

Contrary to impressions gained in the field, the bulk chemical and mineralogic composition of this rock has remained constant throughout the observed weathering sequence. There is no substantial change in chemical components that are normally sensitive indicators of chemical action. No clay is formed. The only appreciable change is progressive oxidation of ferrous iron in pyrrhotite and biotite and the resulting formation of limonite, which is responsible for the pronounced difference in color of the physically weathered debris.

Small amounts of halite deposited by evaporation of sea spray and native sulfur presumably derived from volcanic fumes of Mount Erebus occur in the weathered materials at Marble Point.

Changes of mineral volumes by oxidation and hydration are negligible. The primary mechanism of weathering is frost-wedging. At present the rocks at Marble Point are subjected to approximately 20 freeze-thaw cycles annually.

Rather than establishing what seems to be an unusual case of chemical weathering, the study presents quantitative evidence for the predominance of rock disintegration in polar regions.

FIXED PRESSURE POINTS FOR CALIBRATION OF HIGH PRESSURES

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A free piston gauge has been constructed, capable of a range to 60 kb, and the phase changes in bismuth, thallium, cesium, water and several salts have been determined. Values for various transitions are Bi_1-Bi_2 25.37 ± 0.02 Kb., Bi_3-Bi_5 26.96 ± 0.18 Kb., Tl_3-Tl_5 36.69 ± 0.11 Kb., Cs_1-Cs_2 22.6 ± 0.6 Kb., Cs_2-Cs_3 41.7 ± 1.0 Kb., Ice_6-Ice_7 21.42 ± 0.04 Kb.

New determinations of the cesium and thallium points suggest that the pressure scale currently in use is approximately 30 per cent in error above 35 kb and recently published data on the stability field of diamonds and the pressure coefficient of the melting point of iron need revision.

ATTEMPT TO DETERMINE THE ANTIQUITY OF ANCIENT FIRED OBJECTS BY EXAMINATION OF THERMOLUMINESCENT GLOW CURVES

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In theory, the thermoluminescent glow curve of an ancient fired object should be proportional to the age of an object, its susceptibility to radiation damage, and its mean radioactivity. The thermoluminescent glow curves of a group of 16 Greek pot sherds have been determined. These pot sherds

range in age from 1580 years B.P. to 2900 years B.P. The mean radioactivity of these pot sherds was determined, their thermoluminescent glow curves were determined, and the susceptibility of radiation damage was determined by subjecting them to a small dosage of 20 m.e.v. protons from a cyclotron. From these data, the relative age of the samples was computed. The age, determined by thermoluminescence, correlates closely with the actual age. The thermoluminescent age in 13 out of 16 samples was within 200 years of the true age, and the maximum error in age determination was 400 years.

ORIGIN OF URANIUM-VANADIUM DEPOSITS IN THE LISBON VALLEY AREA, SAN JUAN COUNTY, UTAH

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The source of metals and the mechanism of concentration for uranium-vanadium deposits on the Colorado Plateau are unknown. However, geochemical studies of deposits in the Triassic Chinle formation, Lisbon Valley area, suggest a source and mode of origin compatible with observations of the deposits.

These deposits occur in continental sandstones at the base of the Chinle. They are overlain by Chinle mudstones and underlain by an erosional unconformity which truncates red mudstones and arkosic sandstones of the Permian Cutler formation. During compaction of the Cutler beds carbonate- or bicarbonate-bearing connate water probably was squeezed from them and moved through Cutler sandstones updip to the basal Chinle sandstones and thence updip to zones of relatively high vertical permeability along the faulted Lisbon Valley anticline. Dissolved high-valent uranium and vanadium may have been carried by these waters and precipitated in the reducing environment associated with carbonaceous material in the Chinle. Deposits in the Cutler formation may have formed in a similar manner in local reducing environments.

In Jurassic Salt Wash sandstones, water escaping from adjacent mudstones could have transported the ore metals.

If connate water from mildly to strongly oxidized sediments was the ore fluid, most deposition occurred during periods of greatest compaction. The larger deposits developed within sandstone lenses which provided a channel for large volumes of ground water.

The process or mechanism described may account for most uranium-vanadium concentrations on the Colorado Plateau.

PALEOZOIC SEQUENCES IN THRUST SLICES OF THE SEETOYA MOUNTAINS, NORTHERN INDEPENDENCE RANGE, ELKO COUNTY, NEVADA

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Three structural sequences of lower Paleozoic rocks in the Seetoya Mountains east of Tuscarora, Nevada, are of partly equivalent age. The highest sequence is Middle to Upper Ordovician bedded cherts, quartzite, volcanic rocks, and graptolitic shales, deposited in a western eugeosynclinal belt. This has been thrust southward or southeastward for several scores of miles. Each of two lower sequences includes the same five Ordovician and Silurian formations which differ in thickness and in lithic details. They are predominantly carbonate rocks with some quartz sandstones, deposited in an eastern miogeosynclinal belt. The upper of these latter sequences has been thrust southward or southeastward 6 or more miles.

The eastern sequences were folded, faulted, and eroded in pre-Carboniferous or Permian. Siltstones laid unconformably on the southern of the two eastern sequences may have been derived from rising lands in the eugeosynclinal belt. Nevadan or Laramian thrusting carried a thick plate of

rock of the western belt southerly or southeasterly. The presence of younger rocks beneath the thrust in the south suggests that a regional southward slope occurred at this time. A second thrust which developed within the eastern belt may be a subsidiary thrust initiated by movement of the overriding rocks of the western belt; this thrust shows a close similarity to the peel thrusts of the western Alps. Block faulting during the Tertiary is largely responsible for the present-day north-south trend of the range.

ENGINEERING GEOLOGY OF GEOTHERMAL STEAM DEVELOPMENT

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The search for areas having abnormally high geothermal gradients and development of the untapped, evolved steam for low-cost power and industrial uses is a growing field for the geologist. Geothermal heat, already utilized abroad, is undergoing exploitation in western United States; the first power plant began operating during 1960. Numerous potential areas are being explored and tested, many in regions lacking hydroelectric resources.

Geothermal fluids are associated with: (1) active or late Cenozoic volcanism; and (2) recent or active faults. Fluids are a mixture of magmatic and meteoric waters (White, 1957). The convective transfer of heat and magmatic steam occurs along major faults; the most recently active and tension faults are the principal open channelways near the surface.

Although exploitation may require wells up to 4000 feet deep, many sites are developed at less than 2000 feet. Depth to a sustained reserve depends on: site rock (impermeable or permeable) and inherent thermal gradient; frequency and intensity if faulting is active; and proximity to magma. The ideal well should tap the deeper zone of superheated gases because the amount produced influences plant efficiency and economics. Noncondensable gases can be a source of chemical by-products.

Wells may encounter such problems as: blowouts; variable output and clogging; dilution by inflow; and excessive steam losses requiring consolidation grouting.

Additional case histories supported by detailed geologic, geophysical, and geothermal site studies are needed to improve forecasts. For example, is the maximum energy obtained by one deep, high temperature-pressure well or by several shallow wells supplying a greater volume of lower-temperature fluids?

SANDSTONE PETROGENESIS OF THE WOLFVILLE FORMATION (UPPER TRIASSIC), MARITIME PROVINCES, CANADA

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The Wolfville formation is a postorogenic, fluvial red-bed sequence consisting of interbedded conglomerate, coarse- and medium-grained sandstone, and claystone. It ranges in thickness from 200 to 1200 feet.

Modal analyses of 85 thin sections of sandstones show that orthoquartzite, low-rank graywacke, high-rank graywacke, impure arkose, and arkose occur in the Wolfville formation. Low-rank graywacke is limited in distribution to areas where the Wolfville overlaps Lower Paleozoic metamorphic rocks and Mississippian sedimentary rocks. High-rank graywacke, impure arkose, and arkose occur where the Wolfville overlaps Devonian granite or where granite intrudes Lower Paleozoic metamorphic rocks. Orthoquartzites are found where the Wolfville overlaps or is faulted against Pennsylvanian sedimentary rocks.

Mapping of 2443 directional-current structure azimuths at 67 localities suggests that the different sandstone types were derived from the pre-Triassic rocks which the Wolfville overlaps and that the lateral variation in sandstone composition is controlled by lateral change in source-area rocks.

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Comparison of the composition of the sandstones of the Wolfville formation with ancient sandstones and modern sands supports the conclusion that source-area composition, rather than tectonics, exerts a greater influence on sandstone composition.

LARAMIE ANORTHOSITE

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For the last 2 years a detailed mapping program has been carried out on the Laramie anorthosite and the adjacent Precambrian rocks, in southeastern Wyoming. To date the northern half and the southwestern part have been completed, and a gravity survey of the mass and its environs has been undertaken.

The northern and western parts of the mass have a well-defined gabbroic border facies, but on the east the border facies is absent, probably because of the intrusion of the Sherman granite in this part. The presence of small patches of gabbroic anorthosite on the anorthosite lends support to the theory that the anorthosite was enveloped in gabbroic anorthosite.

Much deformation after the intrusion of the Sherman granite is shown by the extreme granulation and brecciation of the anorthosite and the intrusion of acidic dikes along breaks with a roughly north-south strike. Roof pendants of gabbroic anorthosite and ilmenite-magnetite lie within the hypersthene syenite and hornblende syenite bodies which intrude the margins of the anorthosite mass on the north and west. In the southwest roof pendants of para- and orthogneisses lie in the anorthosite.

Preliminary gravity work indicates a thickening of the mass toward the center.

PHYSICAL PROPERTIES AND ENGINEERING CHARACTERISTICS OF MISSISSIPPI LOESS

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Precipitous uplands, blanketed with loess, border the flood plain of the Mississippi River from Cairo, Illinois, to St. Francisville, Louisiana. More than 300 miles of these north-south-trending uplands are in Mississippi. Loess deposits begin about 20 miles east of the bluff line. They reach a maximum thickness of 60 feet.

Recent earth-moving operations for highway and residential construction near the larger towns have opened deep vertical cuts in the loess. Details of megascopic characteristics are well revealed—*e.g.*, concentric banding in many of the cut faces, the concentration of pulmonate gastropods and concretions in specific zones, the coincidence of present topographic highs with highs on the underlying Pleistocene. Engineering properties of the loess are strikingly uniform. Typically, liquid limits range between 23 and 30, plasticity indices between 0 and 10, water contents between 18 and 25, and densities between 75 and 105 lbs./cu. ft. Only about 10 per cent of the material is finer than silt, and much less is coarser. Grain size decreases slightly downvalley and more perceptibly eastward from the bluffs; it remains essentially constant from the bottom to the top of any one exposure.

Highway engineering problems include proper compaction of fill and design and protection of high cuts. Foundations weakened through saturation have been noted beneath small dams. Foundations for commercial and residential buildings are generally uninvestigated and in many cases prove inadequate from an engineering standpoint.

HYDROTHERMAL CONVERSION OF MUSCOVITE TO KALSILITE AND AN IRON-RICH MICA

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Attempts to grow large single crystals of muscovite using muscovite cleavage plates as seeds and shredded muscovite as nutrient produced an iron-rich mica and considerable quantities of the $KAlSiO_4$ polymorph called kalsilite. This is of interest, since kalsilite is not a common mineral in nature. It was first discovered in volcanic rocks from SW. Uganda by Bannister and Hey (1942) and first synthesized in the laboratory by Rigby and Richardson (1947).

The following conditions prevailed during the hydrothermal synthesis of the kalsilite and iron-rich mica described here:

Seeds and nutrient	Natural muscovite
Solvent	KOH (1 N solution)
Partial fill	70 per cent
Temperatures	
Seed area	Approximately 410° C
Nutrient area	Approximately 425° C
Estimated pressure	1200 bars
Bomb liner	Cold rolled low-carbon steel, 1″ O.D., ⅞″ I.D.

Crystals of kalsilite up to 3.5 mm in diameter were obtained in a run lasting 14 days. The kalsilite was fairly well crystallized, but multiple growths were abundant. It was possible to mount some of the better single crystals on a small two-circle goniometer to measure interfacial angles. The following forms were observed:

Form	$\rho \pm 2°$	$\phi \pm 2°$
{0001}	0	
{10$\bar{1}$0}	90°	60-degree intervals
{10$\bar{1}$1}	61°	60-degree intervals
{20$\bar{2}$3}	46°	60-degree intervals

SELECTED PARAMETERS FOR CORRELATION WITH K_2O AND TiO_2 CONTENT OF HIGH-SILICA OUTCROP SAMPLES FROM SOME LOWER PENNSYLVANIAN SANDSTONES OF THE EASTERN INTERIOR BASIN

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A new approach to geological correlation of sandstones occurring in the Caseyville and Tradewater groups of the Pennsylvanian system of the Eastern Interior basin is indicated by statistical studies and graphic correlation on cartesian co-ordinates of the K_2O and TiO_2 content of certain high-silica outcrop samples, for certain physical and chemical parameters.

The K_2O content of washed +270-mesh sandstones samples shows excellent graphic correlation plotted against A. F. S. (American Foundry Society) clay percentage (fraction finer than 20 microns);

* Operated for the Atomic Energy Commission by Union Carbide Corporation

this correlation is considered significant after considering the marked heterogeneity of source rocks for both sandstone groups.

The K_2O content shows fair graphic correlation against the G. F. N. (grain-fineness number) for the Caseyville sandstone samples gathered from the Gorham locality; this correlation is considered similarly a fair relationship for the Fe_2O_3/MgO ratio plotted vs. G. F. N. for the same set of samples.

The TiO_2 content shows fair graphic correlations plotted vs. the Fe_2O_3 content for washed, acid-treated, and magnet-treated runs of the Caseyville samples.

SEASONAL DISTRIBUTION OF OSTRACODES IN TEXAS BAYS AND LAGOONS

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Semiquantitative samples of living ostracodes were collected each month from November 1958 through October 1959 from fixed stations located in Copano Bay, Redfish Bay, and the upper Laguna Madre of Texas. In each area ostracodes were more abundant during summer months when plant production was highest, showing more than a 10-fold increase in some areas. Ostracodes were more abundant in Redfish Bay where the salinity ranged from 16 to 38‰ than in the upper Laguna Madre where the salinity rose to 50‰ during the summer or in Copano Bay where the salinity dropped to 10‰ during the winter. Species diversity indices obtained by determining the number of species in 300 living ostracodes randomly selected from each sample indicated that the ostracode population was more diverse in Redfish Bay than in Copano Bay or the upper Laguna Madre. Species diversity was greater in the spring and fall seasons than in the summer and winter seasons. These diversity relationships could be demonstrated, whether calculations were made on the basis of number of species per 300 ostracodes or number of species per equal area of bottom. In Redfish Bay the species *Hemicythere conradi* formed 90 per cent of the population during summer months, but during the winter a species of *Losoconcha*, whose abundance remained approximately the same during the year, made up 55 per cent of the ostracode population. The species diversity of empty carapaces in the sediment, which represent the accumulation of many seasons, was greater than the diversity of species living in the area during any one season.

ANCIENT SHORE-LINE SEDIMENTARY ROCKS OF PERMIAN AGE, NORTHERN PEDERNAL HILLS, NEW MEXICO*

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The Pedernal Hills, a 250-square-mile area of Precambrian rocks in central New Mexico, are predominantly rounded granite knobs giving way northward to rugged metaquartzite ridges culminating at Pedernal Mountain (altitude 7580 feet). This was a high part of the more extensive, upper Paleozoic Pedernal land mass, which was not buried by sediments until middle(?) Leonardian time or later. Pennsylvanian and Wolfcampian strata, not present in Pedernal Hills, are 4700 feet thick 8 miles to the west in the Estancia basin.

Basal Paleozoic rocks in Pedernal Hills are the Permian Yeso formation, deposited around 200- to 800-foot metaquartzite ridges, and consist of tan, even-bedded, porous, marine sandstones bearing oscillation ripple marks. Interbeds are of shaly siltstones and oölitic sandy limestone containing scattered angular metaquartzite fragments. Talus blocks in a sand matrix border some ridges, grading laterally into "breccia" conglomerate lenses. The few cross-laminated sandstones probably represent deltaic and dunal deposits.

* Published by permission of the Director, State Bureau of Mines & Mineral Resources Division, New Mexico Institute of Mining & Technology

The tan sandstones appear to be reworked local alluvium that partially covered the Pedernal land mass during early Permian time; they underlie reddish-orange silty sandstone, of bimodal grain-size distribution and with subrounded to rounded grains, which is the basal Yeso in much of central New Mexico and apparently was chiefly derived from uplifts to the north. The Pedernal land mass ceased being a major source of detritus when the Pedernal Hills were buried by Permian sediments.

Similar Pennsylvanian-Permian shore-line sedimentary rocks abutting against presently buried remnants of the Pedernal land mass are possible oil-bearing stratigraphic traps in central New Mexico.

SUBMARINE GEOLOGY NEAR GUADALUPE ISLAND

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A relatively stable block of the oceanic crust about 50 miles square lies at a depth of about 1900 fathoms in the northeast Pacific Ocean east of Guadalupe Island, which is a large basaltic volcano. The region is a potential site to obtain drill cores of the oceanic crust. It is bounded on the north by a graben, which is in turn bounded by an east-west escarpment more than 5000 feet high and by associated volcanoes. On the east lies the Cedros deep which in turn is bounded on the east by the continental slope. To the south, the block drops into characteristic oceanic depths via a monocline. At present, the block is surrounded by a deeper floor and therefore cannot receive bottom-transported sediment. Geomagnetic profiles reveal north-south anomalies typical of the northeast Pacific Ocean oceanic crust.

The recent geologic history of the region is inferred as: development of the continental borderland and Cedros deep in late Cretaceous and Tertiary time with isolation of the region from continental sediments; typical deep-sea sedimentation through late Tertiary time; Pleistocene and Recent deformation and volcanism contributing an unknown quantity of ash and debris to the stable region, although the amount may be small. The block is relatively undeformed because of the local neutralization of orogenic stresses. The crust is shoaler than the typical oceanic floor because of (1) structural support such as an uplift of the crust because of isostatic load of Guadalupe Island, or (2) chemical and/or physical changes in the mantle.

PEGMATITES IN GRANITIC ROCKS, NORTHERN MANITOBA, CANADA

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A large area surrounding Northern Indian lake is underlain by Precambrian granitic rocks. The rocks are composed essentially of plagioclase, K feldspar, quartz, biotite, and hornblende and contain numerous pods and dikes of pegmatite, which is composed essentially of plagioclase, K feldspar, quartz, and biotite.

The zone of rock around some pegmatite masses contains large amounts of a mineral that is present in small amounts in the pegmatite (*e.g.*, biotite, plagioclase) and small amounts of a mineral that is abundant in the pegmatite (*e.g.*, K feldspar). This feature demonstrates that the pegmatite has formed by a local rearrangement and recrystallization in granitic rock. The rearrangement necessitates a movement of matter in opposite directions, an operation which cannot be accomplished by any type of fluid but can be accomplished by solid-state diffusion.

Where the minerals involved in the diffusion process are solid solutions, a comparison of mineral compositions across a pegmatite-granite contact makes possible a determination of relative diffusion rates. For example, at one contact where plagioclase has moved from a place now occupied by pegmatite to the adjacent granite, the plagioclase remaining in the pegmatite is less sodic, and the

plagioclase in the adjacent zone is more sodic than in the surrounding granite. This implies a greater diffusion coefficient for $NaAlSi_3O_8$ than for $CaAl_2Si_2O_8$.

GEOLOGY OF THE DECATURVILLE DISTURBANCE IN MISSOURI

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The area of the Decaturville uplift comprises 20 km² in Camden and Laclede counties in West-Central Missouri. The present study is based on detailed surface mapping, 4 open pits, 85 diamond-drill, and 5 churn-drill holes, with an aggregate footage of approximately 22,000 feet.

The sedimentary rocks consist of sandstones, dolomites, and shales of Cambrian and Early Ordovician age. In the center a granite pegmatite body is exposed, and isolated pegmatite apophyses or wedges have been met at a few places in different drill holes. A mylonitic sericite schist zone surrounds the outcropping pegmatite.

The lead, zinc, and iron sulfide mineralization within the structure is restricted almost exclusively to some portions of a strongly brecciated zone, which may correspond to a fault zone in the sedimentary rocks.

All rock units are disturbed by multiple rejuvenated faulting. Some portions of the drill core show overturned and overthrust, repeated sequences. The beds immediately surrounding the pegmatite, to a distance of 2 km away from it, exhibit variable dip and strike, in many cases even within short distances. The over-all structural pattern is that of a complex, zoned, polygonal uplift, similar to the Crooked Creek structure in Central Missouri and to the other polygonal structures of the Middle West.

The tectonic history and the presence of the pegmatite(s) appear to support the conclusion that the Decaturville disturbance may be caused by polygonal or ring tectonic movements in the basement, connected with or caused by igneous activity.

EVOLUTION OF SEDIMENTARY ROCKS

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Sediments follow an evolutionary scheme paralleling the geotectonic and geochemical development of the earth. Although precursors and throwbacks (similar to Stone Age savages in the twentieth century) occur, the general trend is definite.

Protosediments, directly formed from basaltic crust, not yet discovered, possible analogies in Aleutian Islands

Archaic sediments, mostly Archean, 1.8–3.5 billion years old; partial analogy New Zealand

Historic sediments

(1) *Early Historic: first substage:* Huronian and Algonkian; *second substage:* Cambrian and Lower Ordovician; partial analogy Northwestern Australia

(2) *Middle Historic:* Middle Ordovician to Permian

(3) *Late Historic:* Mesozoic–Cenozoic

Recent sediments, a special, postglacial case; atypical except for general principles

Petrography: High-rank graywackes (chloritic, more than 20 per cent plagioclase), prominent in Archaic stage, decrease considerably later. Arkoses are important during Archaic, first Early Historic substage, and during Late Historic stages. Orthoquartzites appear and are predominant during Early Historic and then decrease. Low-rank graywackes (illitic) begin in Early Historic and in their "D" type (less than 10 per cent feldspar) dominate Middle Historic; they change partly into "F" type (10–20 per cent) in Late Historic. Carbonates appear first in Early Historic, and their inor-

ganic-microcrystalline group, with syngenetic dolomites, dominates until Middle Historic, when the bioclastic group gains ascendency.

Petrology: Noticeable changes in environmental imprint, field appearance, and rock-body geometry mark breaks between stages. For instance, step-by-step oscillatory carbonate cyclicity is considerably reduced after Early Historic, and, conversely, first large-sized deltas appear only in Late Historic stage.

These statements apply to Northern Hemisphere, excepting Western Europe.

PRIMEVAL OCEAN

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The total amount of Ca and Mg in sea water (1672.1 ppm), if totally transformed into carbonates, would blanket continental surfaces with an average layer 17 ± 2 m thick compared with actual carbonate thickness of 540 ± 90 m produced from sedimentary cover (author's estimates). This discrepancy exceeds a factor of 30 times. No sizable carbonate rocks occur before Huronian-Grenville time, 1.7–2.0 billion years ago.

The hypothesis is advanced that waters of the Primeval Ocean, 2–4 billion years ago, contained 2.5–5 per cent alkali metals, mostly Ca and Mg leached from original basaltic crust, or 2–4 times more than the present combined Na, Ca, Mg, Sr content.

Massive carbonate precipitation occurs only in shallow seas, preferably on flat shield-periphery platforms. These appeared when rugged small Archean protocontinents (New Zealand type) coalesced during Huronian into large continental shields subject to peneplanation.

From Huronian time on, 1.5–2.0 billion years ago, carbonates were systematically subtracted from the ocean and deposited mostly on undeformed shield peripheries little subject to later erosion. This eliminates major recirculation and recycling of Ca and Mg at least until Appalachian-Hercynian uplifts.

This permanent extraction of Ca and Mg from the ocean reached an almost universal peak during Algonkian–Early Paleozoic, 300 million–1 billion years ago.

Uneasy equilibrium with sizable recirculation prevailed after great continental uplifts in Mesozoic.

This hypothesis, honoring the memory of Werner, is independent of conventional NaCl salinity-increase theories; it opens vistas for re-examining the origin of life and locating Precambrian faunas.

Cu–S SYSTEM

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The system Cu–S has been studied systematically from 50° to 1150° C. by evacuated sealed silica-tube experiments, differential-thermal analysis, and X-ray diffraction at high temperature. Compounds in the system are Cu_2S, occurring in three crystalline modifications, two polymorphs of Cu_9S_5, and CuS, which has a hexagonal structure over its entire stability range. CuS is stoichiometric, within the limits of $CuS_{1.000\pm0.003}$, and melts incongruently at 507° C. Digenite, which is rhombohedral at room temperature, inverts on heating to a cubic structure (Fd3m) at 65° C. This high-temperature form is nonquenchable. Orthorhombic chalcocite inverts on heating to a hexagonal form at 100.3° C. On further heating it becomes cubic (Fd3m) at about 460° C. Neither the hexagonal nor the cubic form is quenchable. Complete solid solution exists between the cubic polymorphs of Cu_2S and Cu_9S_5 above approximately 500° C. Chalcocite does not form measurable solid solution with copper. Digenite in equilibrium with covellite takes 0.6 weight per cent sulfur into solid solution at 500° C. and in equilibrium with a liquid takes 1.1 weight per cent sulfur into solid solution at 800° C. The solidus and liquidus relations were investigated from 2–95 weight per cent Cu. The melting relations of

chalcocite are in close agreement with those given by Jensen (1947). A two-liquid field between Cu and Cu_2S above 1105° C. was reported by Heyn and Bauer (1906). The system has now been found to contain a second two-liquid field above 813° C. and over the wide composition range from about 2–73 weight per cent Cu.

METAMORPHIC EVENTS IN THE SOUTHERN APPALACHIAN MOUNTAINS

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Numerous new K–Ar isotopic ages on micas and hornblende separated from igneous and metamorphic rocks of the Blue Ridge and Piedmont provinces make it possible to define more clearly the boundaries of the areas subject to each successive metamorphic event. Although the initial basement was older, a widespread metamorphism may have affected the area at about 850 m. y. ago. The next major event took place between 450 and 550 m. y. ago. At 350 m. y. ago metamorphism occurred all along the western border of the Southern Appalachian province and may have extended east of the Fall Line. The latest event at about 250 m. y. appears to have affected a much narrower belt. Its eastern margin lies west of the Fall Line. Each of these metamorphic events appears to have occurred over the entire Appalachian region.

MEEKOCERAS FAUNA: AN APPRAISAL OF ITS COMPOSITION AND CORRELATION

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The *Meekoceras* fauna is the most widely distributed, best known, and largest of the Lower Triassic (Scythian) ammonoid faunas of the western United States. It comprises 27 genera and approximately 60 species. In an attempt to re-evaluate the correlation of the *Meekoceras* fauna, G. G. Simpson's index of faunal resemblance (at the generic level) has been applied to 16 faunas from the Arctic, eastern Pacific, and Tethyan realms. Many of these faunas have been placed by previous authors in higher or lower zones. The larger faunas with nine or more genera generally show high indexes of similarity with the *Meekoceras* fauna of western United States. These are the Barabanja fauna of Madagascar, the *Hedenstroemia* fauna of the Himalayas, the *Pseudoflemingites* fauna of Timor, the *Owenites* fauna of Timor, and the *Owenites* fauna of Kwangsi, China. Faunas with six or fewer genera (from New Zealand, Japan, Siberia, Arctic Canada, Spitsbergen, and Yugoslavia) yield erratic indexes because of the small number of genera but because of the presence of certain forms are believed to be correlative with the American *Meekoceras* fauna. Discrepencies in the indexes among some of these faunas are believed to be due to factors of facies, collection failure, and lack of study. Comparisons by means of the same index of the total fauna within each of the main paleogeographic realms yield high indexes; this lends support to the comparisons of individual faunas.

SNOW STUDIES ON THE INLAND ICE OF NORTH GREENLAND

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Snow studies were conducted at selected locations during a 2500-km (1600-mi) inland traverse on the North Greenland Ice Cap in 1959. Twelve deep pits (5–5½ m) were excavated over an altitude range of 1420–2215 m. Density and hardness measurements, as well as stratigraphic observations, were made over the continuous pit profiles, where the annual accumulation was measured for as

many as 13 consecutive years. Temperature measurements extend over a 10-m depth. Rammsonde stations were regularly interspaced between the pits in an attempt to trace significant index horizons.

The mean annual accumulation varied at each location, and the data show a different rate associated with the various legs and surface slopes of the traverse. The various accumulation profiles decrease inland and with elevation at a mean rate of 1.5 g/cm³ per 100 m. The results show a general accumulation rate of about 19 cm water equivalent per year, which is approximately twice the amount previously predicted for North Greenland.

The 10-m-deep firm temperature measurements reflect the mean annual surface temperatures. Using these values from all stations gives a mean altitude-temperature gradient of 0.77° C. per 100-m change in elevation. Distinctly different gradients exist for the various traverse legs and surface slopes. The mean density of a location is shown to be an environmental indicator representing the summation of past climatic events. Evidence of melt was observed at all locations; the 1954 summer was the most pronounced.

Empirical correlations of altitude and latitude with accumulation, temperature, and density show linear relationships which suggest that the entire geographical district of inland northwest Greenland is subjected to similar climatic conditions.

PHOTOMICROGRAPHY OF THE CORNWALL MAGNETITE ORE BODY, CORNWALL, PENNSYLVANIA

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The Cornwall magnetite deposits, Cornwall, Pennsylvania, are considered to be a type deposit for metasomatic limestone replacement ore spatially and genetically associated with a diabase intrusive. Recent studies show that the genesis of these ores is more complex than previously believed. One of the most important of these studies has been a systematic petrographic examination of ore and gangue interrelations vertically and laterally throughout the more recent eastern ore body. Thin-section color photomicrographs reveal that (1) the diabase is not noticeably depleted in iron content; (2) fissure veins cut, and disseminated magnetite replaces, the diabase chill zone from the top downward; (3) amphibolitization, chloritization, and sericitization of the upper part of the diabase increase toward the ore contact; (4) crystallization of the diabase was followed first by thermal and metasomatic silication, later by metal sulfides and oxides, and finally by late, low-temperature hydrous silicates; and (5) ore-localization controls include the composition of the host metasedimentary rocks, primary compositional bands within these metasedimentary rocks, grain-size textures both of the metasedimentary rocks and of the metasilicates, and the quantity distribution of the metasilicates, especially pyroxene and amphibole. Lateral and vertical mineral variation is present with respect to the ore footwall at the diabase contact. From the petrographic evidence it may be concluded that the ore was emplaced later than the diabase crystallization, that it is associated with hydrothermal mineralization, and that replacement locally is compositionally and texturally controlled.

HYDROTHERMAL EFFECT ON CRETACEOUS VOLCANIC ROCKS IN SOUTHWESTERN KIANGNING DISTRICT, KIANGSU PROVINCE, CHINA

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Cretaceous volcanic rocks in southwestern Kiangning District consist of andesite, trachyte, and ferruginous tuff. These rocks cover about 250 square miles and are locally overlain by the Hanfushan sandstone. The andesite consists mainly of andesine, hornblende, augite, and some biotite in a groundmass of abundant laths of plagioclase and aggregates of iron oxides. The trachyte contains altered

potassium feldspar and biotite in a kaolinitized groundmass. The ferruginous tuff is composed of entirely altered feldspar in an earthy groundmass. These rocks were intensively altered hydrothermally by diorite and monzonite intrusions during latest Cretaceous time. The alteration sequence has been defined tentatively as: silicification and sericitization preceded epidotization, chloritization, and kaolinization that were followed by silicification and carbonatization.

The alteration products are secondary quartz, sericite, epidote, chlorite, kaolinite, and calcite. Potassium, alumina, silica, calcium, and iron were provided by the diorite and monzonite intrusions during the processes of alteration. Most andesine and potassium feldspar grains have been replaced by secondary quartz, sericite, epidote, kaolinite, chlorite, or calcite. Augite, hornblende, and some biotite have been partly altered to epidote and chlorite. Calcite veinlets commonly cut across the andesine and the groundmass.

Widespread hematitic fissure filling in the volcanic rocks is associated with the alteration. The iron-bearing solution that formed these deposits was probably introduced in the last phase of silicification, as indicated by the occurrence of ferruginous rims in the silicified volcanic rocks.

EXPERIENCES WITH GROUND WATER ON CONSTRUCTION

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Local ground-water conditions are generally disrupted by construction operations even when well-accepted methods of handling ground water are used. In most cases, natural conditions are restored once a structure is completed, but some engineering projects necessarily cause permanent change in previously existing ground-water conditions. Some unusual Canadian examples include the "control" of ground water at Steep Rock Iron Mines by trapping it before it reached the drained lake bed in order to obviate erosion of the lake-bed deposits; the Aguasabon hydroelectric development on the shores of Lake Superior, where a "perched reservoir" is used as the main forebay in an area of pervious sand and gravel, and glacial silt forms a natural basin in this pervious material; La Tuque hydroelectric development of the Shawinigan Water and Power Company on the St. Maurice River, where seepage around a large concrete dam shows itself in a small natural lake, the level of which has to be controlled by pumping.

BEARING OF THE LOESS DEPOSITS ALONG MISSISSIPPI RIVER VALLEY ON THE STREAM'S REGIMEN DURING LATE PLEISTOCENE

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World-wide changes in sea level during glacial ages are generally recognized, and valley deepening and aggradation are generally conceded to have accompanied the fall and rise of sea level, respectively. Various opinions are held on how far up the valleys these processes were effective.

The loess deposits along Mississippi River Valley afford some measure of the extent of valley-train deposition down the river from the glacial front, because the loess was blown from valley trains. Deposition extended to a point a short distance below Natchez, Mississippi, as inferred from the map of Eolian deposits of North America, where the loess deposits end. The river was overloaded to that point, beyond which the gradient to the lowered sea level was sufficient for the stream to carry its load, to become erosive, and to entrench itself for the remaining distance to the sea.

Farmdale, Iowan, Tazewell, Cary, Mankato, and Valders glaciers all had valley trains. During the intervals between the glacial substages, great floods of melt water from the glaciers of both continents were returned to the sea, raising the sea level as well as sweeping out the valley trains and cliffing the valley walls.

These and other phenomena make it apparent that the Pleistocene history of Mississippi River

will be revealed in more detail when both the glaciated area to the north and the unglaciated area to the south are studied as a unit.

SELENOGRAPHY OF SOME PROMINENT LUNACRATES

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Selenography involves the study of the relief features of the lunar surface—a surface considered to be of Precambrian age. The features include great mountain systems, fracture patterns, highland areas, lava flows, and thousands of craters (lunacrates).

The craters range from a few hundred feet to 140 miles in diameter, and their depths range up to 12,000 feet. Some have relatively flat floors; others are covered with rubble debris. In some craters, central peak complexes rise several thousands of feet above the floor. Concentric landsliding is prominent on the inner escarpment slope of the larger ones. Radiating percussion dust rays and radial grooves are conspicuous around some of the younger craters.

Specific characteristics of 13 major lunacrates are discussed (Plato, Copernicus, Erathosthenes, Hell, Alpetragius, L-3, Piazzi Smith, Wallace, Aristillus, Alphonsus, Thebit, Archimedes, Sinus Iridium).

Considerable controversy prevails concerning the origin of lunar craters; the writer supports the impact-explosion theory which involves contact of high-velocity solids from outer space. However, a volcanic origin for some of the smaller craterlets is possible, particularly those appearing to be closely associated with major fractures.

POORLY CRYSTALLIZED, LOW BARIUM, PSILOMELANE-TYPE MINERAL

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Specimens which have been recognized as poorly crystallized psilomelanes or psilomelane-type minerals have been mentioned in the literature for about 30 years. However, no detailed study of any of these minerals is recorded.

A manganese mineral from the La Abundancia mine, Zacatecas, Mexico, has been found to be poorly crystallized. Its X-ray-diffraction pattern gives only three distinct lines (2.41, 2.19 and 1.42 Å) as well as a few faint, diffuse bands and lines. Interpretation of the pattern indicates the mineral to be a poorly crystallized psilomelane. Chemical analysis shows the mineral to be very similar to psilomelane except that it contains only 4.5 per cent BaO. Calculations show that the normal barium positions are filled with potassium (K_2O = 1.5 per cent), sodium (Na_2O = 0.7 per cent), calcium (CaO = 1.3 per cent), and strontium (SrO = 1.4 per cent) in isomorphous substitution.

AUTOTHERMOLUMINESCENCE—A NEW PETROLOGICAL TECHNIQUE

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ATL (autothermoluminescence) photographs provide an inexpensive and simple method of obtaining information from a rock section on the distribution of minerals, fractures, and veins, on detailed fabrics, and, in some secondary dolomites, on relict fabrics of the primary rock. These photographs are made by placing a thin slice of rock on a hot plate and then photographing the glow that is emitted. The glow persists for only 1–2 minutes, after which the sample must be reactivated by exposure to ionizing radiation—*e.g.*, gamma rays or X-rays—before another ATL photograph can be made. Comparison photographs of the identical portion of the rock section are also made under

white light. Both black and white and color photographs have been made. The color photographs are particularly useful, because a number of the minerals can be recognized by the characteristic color of their glow.

MIOCENE VERTEBRATES OF THE MOJAVE DESERT

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The Barstow formation of the Mojave Desert comprises 2000–2800 feet of sedimentary and minor pyroclastic rocks; its relations to the underlying and overlying formations are unconformable. Most geologists have used Hershey's name "Rosamond series" for this stratigraphic unit, but paleontologists have used "Miocene deposits," "Pliocene deposits," "Mohave beds," "Barstow beds," and "Barstow formation" for this formation in which fossil mammalian faunas of at least two geologic ages occur.

Common *Protohippus, Meryceros,* and the less common key fossils, *Eucastor, Merychippus sumani, Paracosoryx,* and *Paramoceros,* occur in the upper of two unnamed members. This well-known younger fauna is correlated with the Tonopah and oldest Ogallala local faunas, dated by most authorities as late Miocene but by some as early Pliocene.

The upper half of the lower member yields *Brachycrus, Merriamoceros,* and *Merychippus tehachapiensis* of limited occurrence; vertebrates are not known from the lower half of the lower member. This little-known older fauna is correlated with the Sheep Creek and Phillips Ranch local faunas, dated by most authorities as middle Miocene but by some as late Miocene.

Hemicyon and *Gomphotherium* of the younger fauna of the upper member are genera that occur both in the Old World and the New World; most authorities consider them to be late Miocene in age and of importance in intercontinental correlation.

Large-scale geologic maps of the Barstow formation's area of outcrop, by F. M. Byers, Jr., and T. W. Dibblee, Jr., will be published soon.

ORIGIN OF THE BARITE DEPOSITS OF MISSOURI

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Various open pits with bed-rock barite in the Potosi quadrangle, Washington County (which on weathering yield the locally commercial residual deposits), and the sphalerite-marcasite-barite deposit of the Krueger property were studied in detail. Both are located in the Cambrian Potosi and Eminence dolomites.

Barite, marcasite, sphalerite, and galena, all ubiquitous minor constituents of the Paleozoic sedimentary rocks from Canada to Texas, are here found in two geometrically different patterns with gradational transitions: (1) as isolated patches, and (2) as a network, supporting brecciated host rock.

The detailed analysis of fabrics, including crystal-growth patterns, revealed that (1) the barite must have been available when brecciation took place; (2) there is no evidence for replacement or metasomatism, except possibly some solution of host rock during brecciation and diagenesis; (3) the breccias or large conglomerates are of intraformational origin; (4) the origin of the barite as well as of the sulfides is contemporaneous, formed from euxinic muds on the ocean floor.

Of special critical genetic value are top-bottom or geopetal features, crystal-growth directions, and the statistical distribution of horizontal versus vertical fabric elements. Any indication of zoning is readily understood as a syngenetic-sedimentary pattern.

Whereas a contemporaneous origin is also supported by observations of sulfides and sulfates forming at present on ocean floors in euxinic pH-Eh environments, it is not known yet whether here the metals were of purely sedimentary or rather of exhalative volcanic origin.

PYROLYTIC GRAPHITE: AN APPROACH TO SYNTHETIC GRAPHITE

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Pyrolytic graphite or pyrographite, prepared by vapor pyrolysis of hydrocarbons, approaches a synthetic equivalent of mineral graphite. Pyrographite has a lattice unit cell with an edge length of 2.46 Å, essentially that of graphite. The cell height ranges with treatment from 6.90 Å to 6.70 Å, the same as natural graphite. Elemental crystallites of pyrographite have strong preferred orientation parallel to the deposition surface. Pyrolytic graphites have densities up to 98 per cent that of natural graphite. Pyrographite exhibits a dramatic anisotropy of thermal and electrical conductivities parallel and normal to its deposition or basal surface. Thermal anisotropy changes from 100:1 at room temperature to a maximum of 1000:1 at moderately elevated temperatures. Similar anisotropies are known in single-crystal natural graphite, but their reliability is uncertain, since small crystal sizes affect the measurements. Other structure-dependent properties are affected by the anisotropy. A need for the mineralogical classification of pyrographite is emphasized. Further study of the mechanism of origin of pyrolytic graphite should generate additional insight on the formation of natural graphite.

SHELL CHEMISTRY OF SOME RECENT AND PLEISTOCENE MOLLUSKS AND ITS ENVIRONMENTAL SIGNIFICANCE

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Florida Bay is used as a model to show how climatic, geographic, and hydrographic factors can influence the O^{18}/O^{16} and C^{13}/C^{12} ratios and the Sr/Ca and Mg/Ca ratios of shallow-shelf marine waters. Some of the variations in water chemistry are reflected in variations in the chemistry of mollusk shells collected in the bay.

Geographic isolation and high evaporation in the bay coupled with the influx of fresh water enriched in O^{18} produce a gradient of increasing H_2O^{18} into the bay. Dilution of the bay water by Ca-rich fresh water lowers the Sr/Ca in the bay. The gradient of H_2O^{18} in the water is clearly reflected in a similar gradient in the carbonate oxygen of mollusk shells. The effect of temperature on the carbonate isotopic composition is inadequate to explain the variations. Sr/Ca ratios of shells vary but show no simple relationship to environment. A gradient of decreasing C^{13} in shells going into the bay is attributed to the equilibration of CO_2 derived by oxidation of organic debris in the sediment with the carbonate of the water.

Analyses of mollusks from sediment cores show that the present environmental framework of Florida Bay has existed for the last 3700 years. Analysis of the fine-grained sediment of the bay suggests that part of it is derived from the Florida mainland.

Fossil mollusks from the Pleistocene Caloosahatchee formation were analyzed. The O^{18}/O^{16} ratios coupled with geological and faunal data indicate an environmental framework strikingly similar to the Florida Bay model. A landmass immediately west of the outcrop area is postulated for most of Caloosahatchee time. The carbon-isotope and strontium data reveal little environmental information.

SOURCE OF WATER ISSUING FROM SPRINGS IN ASH MEADOW VALLEY, NYE COUNTY, NEVADA

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Six large springs in Ash Meadow Valley, Nye County, Nevada, discharge about 18,000 acre feet of water annually. The springs are significant in that they occur in the middle of a large arid region

of the State. Precipitation within Ash Meadow Valley and the contiguous Amargosa Desert is insufficient to account for the discharge; therefore, movement of ground water from one topographically closed basin to another is indicated. Meager hydrologic data suggest that the source of much of the discharge is precipitation on the west slope of the Spring Mountains, which border the east side of Pahrump Valley, about 30 miles to the east.

LAND SUBSIDENCE ADJACENT TO THE WHITE WOLF FAULT NEAR BAKERSFIELD, CALIFORNIA

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Movement along the White Wolf fault south of Bakersfield, California, in July 1952, caused one of California's major earthquakes. Numerous fractures and cracks developed in the unconsolidated valley deposits. Releveling and triangulation by the Coast and Geodetic Survey after the earthquake defined a major flexure that had developed in the land surface parallel with the trace of the fault. Differences in benchmark elevation from 1947 to 1953 indicated that the area south of the fault had been uplifted nearly 2 feet and the area to the north lowered by a comparable amount.

Recent surveys have indicated an area of active "nontectonic" land subsidence adjacent to the White Wolf fault. Much of the downwarping north of the fault zone, earlier interpreted as tectonic adjustment associated with the 1952 faulting, now is attributed to compaction of unconsolidated valley sediments caused by decline in ground-water levels.

Subsidence in a 200-square-mile area began about 1940 and is continuing at a maximum rate of more than 0.5 foot per year. Water levels in wells in this area are declining from 15 to 25 feet per year.

Water wells in the south end of the San Joaquin Valley suffered serious damage during the 1952 earthquake. Probably more damage, however, has resulted from the continuing compaction of the valley deposits since 1952. Land subsidence in this and other areas of the valley is of serious concern in the present and future construction and maintenance of canals, highways, and large structures.

CLASSIFICATION AND ENVIRONMENTAL SIGNIFICANCE OF STROMATOLITES

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This paper proposes a new classification of stromatolite structures based on their geometric forms and relates these forms to their sites of growth relative to sea-level environments. The classification uses the arrangement of the basic geometric units (hemispheroids and spheroids) from which common stromatolites and oncolites are built.

Three main types of these geometric structures occur in Recent stromatolites and oncolites: (1) laterally linked hemispheroids (LLH), (2) discrete, vertically stacked hemispheroids (SH), and (3) discrete spheroids, which occur either as randomly stacked hemispheroids or concentrically arranged spheroids (SS). The abbreviations are used to designate the various structures conveniently.

Since certain restricted environments are associated with modern stromatolites, ancient environments may be interpreted by recognition of fossil stromatolite forms.

For example, protected intertidal mud flats, where wave action is slight, may be inferred by the presence of type LLH stromatolites (= *Collenia*).

Exposed, intertidal mud flats, where scouring action of waves and other interacting factors prevent growth of algal mats between stromatolites, are inferred by the presence of type SH structures (= *Cryptozoon*).

Low intertidal areas that are exposed to waves and agitated shallow water below low-water mark

are inferred by the presence of type SS structures (= *Oncolites*). The arrangement of laminae in these structures reflects frequency of movement; frequent motion results in concentrically arranged spheroids and occasional motion in randomly stacked hemispheroids.

The inappropriate biological classification of these structures may now be replaced by this descriptive geometrical classification which also has environmental significance.

ISOTOPIC AGES FROM DUTCHESS COUNTY, NEW YORK, AND ADJACENT AREAS

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In Dutchess County, New York, a Cambro-Ordovician sedimentary sequence of quartzite, limestone, and pelite ranging up to Trenton in age is progressively metamorphosed from west to east over a transition zone 3–7 miles wide. Since the age of sedimentation is established (unlike the situation in the Manhattan Prong to the south) the isotopic data from Dutchess County place important limits on the times of metamorphism in southeastern New York. Biotite from the garnet zone has K–Ar and Rb–Sr ages of ~360 m. y. A sample from the sillimanite zone gives biotite K–Ar and Rb–Sr and muscovite K–Ar ages of 360 m. y. The excellent agreement of these with more than 12 isotopic ages in the Manhattan Prong indicates that 360 m. y. was the time of the latest regional thermal event. Muscovite from the above sample preserves an Rb–Sr age of 460 ± 20 m. y., here interpreted as a relic from a prior metamorphic event. According to a current revision of the Geologic Times Scale, this apparent age must also be essentially the true age of the earlier event, both in Dutchess County and the Manhattan Prong, where apparent ages ranging from 360 m. y. up to, but not exceeding, 475 m. y. are found.

Whole-rock K–Ar ages of 400–435 m. y. from isoclinally folded but unmetamorphosed Hudson River pelite west of Dutchess County indicate that any argon which may have been present in old detrital minerals was driven out during folding.

STRUCTURAL IMPLICATIONS OF THE SHORE LINES OF THE MIO-PLIOCENE LAKE NEVADA

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The Mio-Pliocene lake, for which the name Lake Nevada is suggested, in which were deposited the Truckee, Esmeralda, Coal Valley and Humboldt sediments, covered Nevada and northeastern California north of the 37th parallel and, except for local, low areas, west of the 116th meridian below the present elevation of 6000 feet.

Two shore lines hypsometrically related to Lake Nevada sediments are manifest at elevations of 5400 and 6000 feet; the higher shore line is older. The consistent, widespread, development of erosional surfaces at these elevations precludes important subsequent folding or faulting. A Pliocene peneplain was not developed.

Dips of Truckee sediments and penecontemporaneous Kate Peak volcanic rocks in Truckee Meadows are explained by a combination of deposition on rugged terrain and local subaqueous slumping. Mountain fronts east of Slide Mountain and Mount Rose are exhumed fault scarps buried by Kate Peak volcanic rocks that covered part of the Carson Range and partially filled Truckee Meadows and Washoe Valley. The great extent of Kate Peak volcanic rocks indicates many centers of eruption. Lavas and agglomerates were deposited without respect to topography. The Truckee Meadows structural block was formed prior to Kate Peak deposition.

The presence of large granodiorite boulders beneath the Oligocene (?) Hartford Hill rhyolite indicates that relief was great in the early Tertiary. Formation of the Truckee Meadows structural block probably dates from early Tertiary.

Truckee, West Walker, and Carson rivers are superimposed on the Virginia and Pine Nut ranges; they are not antecedent.

GRAVITY STUDIES IN THE BASIN AND RANGE PROVINCE

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In the Basin and Range Province large gravity anomalies are caused by the density contrast between the sedimentary and volcanic rocks of Cenozoic age and the generally more dense older rocks. The anomalies can be interpreted in terms of thickness of the Cenozoic rocks and the structure of the basins that contain them. In many of the basins the Cenozoic rocks extend several thousand feet below sea level; this shows that extensive subsidence of the basins has accompanied the uplift of the nearby mountain ranges. Several basins are formed mainly by faulting, some are formed by a combination of tilting, warping, and faulting, and a few are roughly equidimensional blocks that seem to have subsided following the removal of magma from a magma chamber at depth.

The largest gravity anomalies within the pre-Tertiary rocks are caused by the contrast between the comparatively dense metamorphic rocks and the less dense intrusive and sedimentary rocks. Gravity highs occur over many exposures of Precambrian metamorphic rocks and over contact metamorphic zones associated with large intrusive bodies.

Although there is no evidence that individual mountain ranges are compensated, the regional gravity data show an inverse relation to topographic features that are 100 miles or more in width. Gravity highs are present over all broad topographic lows and gravity lows over all broad topographic highs; this implies that some form of isostatic compensation exists.

APPLICATION OF THERMOLUMINESCENCE TO PROSPECTING FOR HYDROTHERMAL ORES

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A mineral will produce luminescence only on the first application of heat. The light is a result of electrons escaping from traps within the crystal lattice, and once a trap is drained, a second heating will produce no luminescence—provided, of course, there is no new supply of electrons.

Most minerals that exhibit thermoluminescence have glow peaks at specific temperatures. The absence of these sharp peaks should signify that the rock has been heated above the corresponding temperature sometime in the past; the presence of peaks implies either a cold history or else heating with subsequent refilling of the electron traps. Accordingly, the writer proposes to prospect for the "fossil" heat aureole around hydrothermal deposits, using underground drill-hole samples. Young, high-temperature ore bodies should be most amenable to this prospecting technique.

The possibility of prospecting with thermoluminescence was investigated by McDougall (1954), but his study was based on the supposition that radioactive materials are added to the contact aureole, increasing the thermoluminescence within this zone. Even without refined techniques McDougall obtained some positive results.

The present idea was tested on limestones and dolostones at the Bristol Silver Mine, Pioche, Nevada, with some favorable and some conflicting results, which in general were in disagreement with those of McDougall. Further studies are in preparation to determine whether or not thermoluminescence can be used for prospecting, and, if so, which effect (traps drained by heat or traps filled by activators) describes the contact aureole.

CONTROLS ON ORE DEPOSITION AT THE BRISTOL SILVER MINE, PIOCHE, NEVADA

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The Bristol Silver Mine, located 14 miles northwest of Pioche, in Lincoln County, Nevada, produces silver, copper, lead, and zinc from limestones and dolostones of the Cambrian Highland Peak formation. The area has been extensively faulted, and metallization was controlled both by structural and by combined structural-stratigraphic factors.

The ore at Bristol occurs in oxidized replacement bodies as carbonates and silicates, with rare kernels of primary sulfides. The ore bodies have many shapes, from nearly vertical pipes and flat-lying "mantos" to irregular fissures surrounding large breccia fragments. Concentrations of ore are found where faults intersect favorable host rocks, beneath impermeable lithologic zones, in breccia zones, at the intersections of faults, and along single structures where there may have been open or brecciated zones. The principal pipes apparently formed in minor faults where movements of small magnitude developed pinches and swells along the fault surface; the cavities thus opened, which probably contained collapse breccias, permitted the influx of ore-bearing solutions.

ERUPTIVE TECTONIC HYPOTHESIS FOR ORIGIN OF BASIN-RANGE STRUCTURE

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The volume of Tertiary silicic volcanic and hypabyssal intrusive rocks in the Great Basin is about 60,000 cubic miles. Upward movement of this enormous quantity of magma, in episodes that occurred from place to place and from time to time during the Tertiary, was the cause of the block faulting that was similarly distributed in space and time.

A mechanism is suggested by striking similarities in pattern between basin-range structure and the sets of antithetically tilted slump blocks that develop in clay which fails because of withdrawal of lateral support. By analogy, basin-range block faulting expresses a slump-creep movement of segments of the crust toward a "free side" created by upward movement of large bodies of magma formed by fusion of crustal rocks. Field relations indicate that the zone of slump-block failure may extend laterally as much as 150 km from the axial eruptive belt. The geometry of Swedish circle rotation suggests that the depth of the primary magma chambers and the "zone of uncoupling" is about the same as the width of the first-order fault blocks—that is, a few tens of kilometers. This type of eruptive tectonics, associated with silicic magmas and characterized by antithetic tilting of blocks caused by withdrawal of lateral support, contrasts sharply with the broad basining, suggestive of withdrawal of vertical support, that was associated with the outwelling of a comparable volume of basaltic magma in the Columbia Basin.

ORIGIN OF CRYSTALLINE MAGNESITE DEPOSITS

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The magnesite at Gabbs, Nevada, occurs within dolomite—part of the 10,000 feet of conglomerate, limestone, argillite, and dolomite that was deposited in a local embayment of the Upper Triassic sea. These were folded, repeatedly faulted, and intruded by several generations of dikes and a granodiorite stock. The magnesite is involved in all, but its emplacement appears controlled by none, of the intrusive and orogenic history.

Stress-zones within the magnesite are generally dolomitized. Pendants of magnesite within the stock are largely converted to brucite in which apophyses of granodiorite are partly changed to

serpentine. Large masses of dolomite, remote from intrusive rocks, have been transformed to diopside rock.

The deposits at Chewelah, Washington, are similar to those at Gabbs. At Cranbrook, British Columbia, the magnesite occurs within quartzite. Except for the extensive metamorphism of the Grenville rocks, the geologic setting of the magnesite at Kilmar, Quebec, is similar to the Gabbs and Cranbrook deposits. All are interpreted as being sedimentary in origin, having been deposited, with the enclosing dolomite, in shallow, restricted, unstable, marine embayments similar to some of the Caspian Sea in which magnesite and dolomite are presently being precipitated.

The diopside masses at Gabbs, and the roughly concordant serpentine and diopside bands traversing the magnesite at Kilmar, are interpreted as having been formed by metamorphism of contemporaneously deposited silica and carbonates, possibly in the form of a hydrous silica-carbonate gel. Many serpentine and related sills, usually interpreted as being intrusive, may have a similar origin

SULFUR STUDIES OF SELECTED BITUMINOUS COAL SEAMS IN PENNSYLVANIA

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Complete column samples of coal seams were collected from three general areas in the bituminous coal fields of Pennsylvania. The Lower Clarion, Lower Kittanning, and Upper Freeport seams were sampled in each area, and the "Thick Freeport" and Pittsburgh seams were sampled in western Pennsylvania. Four hundred and sixty-three analyses were made for total sulfur and pyritic plus sulfate sulfur with organic sulfur determined by difference. Each sample represented a particular inch level of the seam in question. Petrographic examinations of these samples revealed the major modes of occurrence of pyritic and sulfate sulfur.

From examination of the data the following conclusions appear justified: (1) the average total sulfur content for each seam sampled increases westward across Pennsylvania; (2) the Lower Clarion seam, from sediments deposited in a marine environment, has the highest average sulfur content in each sampling area, whereas the Upper Freeport seam, from sediments of a brackish- or fresh-water origin, contains the least amount of sulfur; (3) organic sulfur shows the least variation within a column sample and is generally between 0.5 per cent and 1.5 per cent; and (4) the distribution of sulfur within the seams is neither top nor bottom preferential, which suggests that the petrographic character of the seam strata may be related to the extent to which sulfur is concentrated.

WELDED TUFFS IN THE NORTHERN TOIYABE RANGE, NEVADA

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Oligocene (?) welded tuffs about 8000 feet thick were laid down in a fault-bounded trough, perhaps a volcano-tectonic depression, about 10 miles wide and 50 miles long in an east-west direction. Detailed mapping at the east end shows that giant boulder fanglomerates are interbedded with the tuffs. These fanglomerates wedge out away from the bounding faults, which indicates that the faults were active during deposition of the volcanic rocks. The densely welded rhyolite units are thick (up to 1200 feet), highly lenticular (up to 2½ miles long), and have one to three layers of vitric tuff near their bases and pumiceous rocks near their tops. Abundant deformed and welded glass shards imply that the rocks were initially hot and fragmental. Chert xenoliths from the subjacent Paleozoic rocks are scattered throughout the tuff units; this attests to highly turbulent flow during emplacement. The sequence contains Miocene or older pollen and is apparently older than Miocene (?) basalts. The deformed welded tuffs are partially overlapped by nonwelded tuffs and epiclastics with early and late Pliocene vertebrate fossils. Both sequences are broken and tilted by north- and northeast-

trending basin-range faults. This thick local sequence contrasts markedly with the thin widespread welded tuffs of eastern Nevada and western Utah recently described by Mackin and Cook.

ROLE OF THE GEOLOGY TEACHER IN PUBLIC EDUCATION

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Public education is geology's best public-relations tool, and the need for increased public awareness of geology has never been more acute than today. The American Geological Institute and the American Association of Petroleum Geologists, through its Public Information Committee, are doing much to place geology in the public eye, but individual geologists can do much to disseminate geologic information at the local level.

Geology teachers, because of their background and experience, should assume an active role in public education. Lay teaching in the community might include work with: (1) Boy Scouts, (2) college-career days, (3) civic clubs, (4) television programs, (5) museum classes and field trips, (6) nontechnical writing, (7) public and school libraries, (8) rock and mineral clubs, (9) public-school science teachers, (10) public-school science classes, (11) science fairs, (12) summer institutes for science teachers and high-school students.

APPLICATIONS OF SOME GEOHYDROLOGIC CONCEPTS IN GEOLOGY

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Subsurface water, an active geologic agent in many geologic processes, must be considered in interpreting geologic phenomena. Principles of the occurrence, distribution, and movement of subsurface waters are well established and readily applicable. In many interpretations in geologic literature, geohydrologic principles have been realistically employed, but in many others these principles have been either ignored or violated.

Explanations of genesis of underclays and associated deposits afford some examples wherein principles of movement and activity of vadose and ground water have been ignored and others in which they have been used advantageously. Postulates stating that waters percolate downward from swamp areas do not allow for the usual movement of subsurface water in such environments. The idea that sediments were leached by vadose water after uplift satisfies the geohydrologic requirements.

Weathering and solution form porous and permeable zones subjacent to unconformities in dense rocks such as carbonates and granites; this illustrates the geohydrologic and economic significance of unconformities. Examples are Mohawkian carbonate aquifers of northern Illinois and oil-bearing Mississippian limestone of eastern Montana.

The flushing effects of meteoric water and other hydrodynamic factors active during erosion periods are important elements in the genesis and concentration of brines. Explanation of the origin and occurrence of brines must include consideration of the geohydrologic environments throughout their geologic history.

ORIGIN OF SLATY AND FRACTURE CLEAVAGE

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Near the Delaware Water Gap, New Jersey-Pennsylvania, slaty and fracture cleavages are well developed in Paleozoic rocks which are not appreciably metamorphosed. The origin of the two types of cleavage may be inferred with some confidence.

The Cambrian to Devonian sedimentary sequence is broken by a major angular unconformity between Martinsburg slate and Tuscarora quartzite. Pebbles of slate occur in the quartzite. Slaty cleavage is restricted to the Martinsburg formation, but fracture cleavage is common in both younger and older formations.

Slaty cleavage, a perfect axial-plane cleavage characterized by well-oriented clay minerals, is present throughout the Martinsburg formation in this area. The Martinsburg was folded at shallow depth shortly after deposition, while the clays and associated sandy beds were water-bearing. Compaction and intense penetrative plastic flowage in the clays parallel to axial planes of folds produced a high degree of clay-mineral orientation. Little bedding-plane slippage occurred.

Fracture cleavage consists of closely spaced semiparallel, semiplanar fractures, developed approximately at right angles to bedding and showing effects of interbed slip. Fracture cleavage is characteristic of many of the shaly and calcareous rocks above the Martinsburg. These rocks were folded following burial to depths of perhaps 7000–10,000 feet; hence the shales were dewatered and nonplastic.

Slate is probably only coincidentally a member of the classic metamorphic progression from shale to phyllite and schist. For rocks deeply buried before folding the progression is more logically shale → fracture-cleaved shale → phyllite → schist.

PELECYPOD ASSOCIATIONS AND ECOLOGY IN THE NEW YORK UPPER DEVONIAN

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A revision of the pelecypods of the Chemung stage (Upper Devonian) of New York has shown that at least six distinctive associations are characteristic of the fauna. Sediment type, associated fossils, and functional analogy with living pelecypods permit the following preliminary ecologic conclusions:

(1) An association dominated by *Grammatodon*, *Mytilarca*, and several pectinoid genera probably represents a byssiferous and free-living epifauna of suspension feeders adapted to life on a stable sand bottom. (2) An association of large numbers of the suspension-feeding epifaunal species *Leptodesma spinigerum*, with smaller numbers of the deposit-feeding infaunal genera *Nuculoidea* and "*Nuculana*", was dominant on organic-rich silt and mud bottoms in areas of weak current action. (3) An association dominated by great numbers of *Cornellites*, with solitary rugose corals, probably represents a "patch reef" epifauna adapted for life on hard shelly bottoms. (4) An association of the deposit-feeding genus *Palaeoneilo*, the suspension-feeding (?) genus *Cypricardella*, and large numbers of spiriferoid brachiopods represents an infaunal pelecypod association adapted to life on stable, organic-rich, sand and mud bottoms that have an abundant brachiopod epifauna. (5) An association dominated by the species *Leptodesma naviforme* may represent either an earlier evolutionary stage or a minor ecologic variant of association (2). (6) An association, containing mixtures of poorly preserved specimens from the other associations, occurs in sandier zones with lenticular brachiopod coquinites and other evidences of strong current action. This association probably originated on unstable sand flats where dead shells from several environments were accumulated by currents.

EFFICIENCY OF GRAPHIC MEASURES FOR DESCRIBING THE MEAN SIZE AND SORTING OF SEDIMENTS

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Present methods for describing the size distribution of sediments include the use of graphic measures, functions of the percentiles obtained from the cumulative size frequency-distribution curve.

In estimating the mean size and sorting of sediments, graphic measures are simply linear combinations of the percentiles.

If a specified percentile is considered as a random variable, as the sample size increases indefinitely, the distribution of the values observed for this percentile tends to a normal distribution. The same is true for any linear combination of percentiles. On the assumption that the logarithm of the grain diameter is normally distributed, it is possible to calculate the statistical efficiency of a given graphic measure. In estimating mean size and sorting, the efficient estimates are the sample mean and sample standard deviation of ungrouped observations. The relative efficiency of a specified graphic measure is the ratio of the variance of the distribution of the corresponding efficient estimate and the variance of the limiting distribution of the graphic measure.

Relative efficiencies of graphic measures currently in use for mean size are: $1/2(\phi_{16} + \phi_{84})$, 74%; $1/2(\phi_{25} + \phi_{75})$, 81%; $1/3(\phi_{16} + \phi_{50} + \phi_{84})$, 88%; for sorting are: $1/1.35\ (\phi_{75} - \phi_{25})$, 37%; $1/2(\phi_{84} - \phi_{16})$, 54%; $1/3.3\ (\phi_{95} - \phi_5)$, 64%; $1/4(\phi_{84} - \phi_{16}) + 1/6.6\ (\phi_{95} - \phi_5)$, 79%.

Suggested graphic measures for mean size are: $1/5(\phi_{10} + \phi_{30} + \phi_{50} + \phi_{70} + \phi_{90})$, 93%; $1/10(\phi_5 + \phi_{15} + \phi_{25} + \phi_{35} + \phi_{45} + \phi_{55} + \phi_{65} + \phi_{75} + \phi_{85} + \phi_{95})$, 97%; for sorting are: $1/5.4\ (\phi_{95} + \phi_{95} - \phi_5 - \phi_5)$, 79%; $1/9.1\ (\phi_{70} + \phi_{80} + \phi_{90} + \phi_{97} - \phi_2 - \phi_{10} - \phi_{20} - \phi_{30})$, 87%. These measures are recommended because of their increased relative efficiency and, for some, greater ease of computation.

HYDRAULIC SHAPE OF MINERAL GRAINS

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The distribution and relative proportions of heavy minerals within a sediment depend on the densities, available sizes, and shapes of the mineral grains. Of these parameters, which influence the fall velocity of a particle in water, shape is the most difficult to evaluate. The literature contains an abundance of different expressions for shape, some of which bear little relation to each other.

The expression that best correlates with hydraulic properties of the particle is its dynamic shape, which represents the hydraulic reaction of the combined properties of grain roundness, sphericity, and surface texture. The dynamic-shape factor is the square of the ratio of the fall velocity of the particle to the fall velocity of a sphere of equal volume and density: $DSF = (v_p/v_s)^2$. It can be estimated from measurements of the three mutually perpendicular axes of the particle (a, b, and c) by applying a correction to the Cory Shape Factor: $S_f = c/\sqrt{ab}$. The correction depends on the values of the axial ratios, b/a and c/b.

CROSS-BEDDING FORMED BY SAND WAVES IN MISSISSIPPI RIVER POINT-BAR DEPOSITS

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In a recent deep cut in Mississippi River point-bar deposits along Old River near Innis, Louisiana, laminated silty clays overlie cross-bedded sand; the contact marks the time of Shreve's cutoff (1831). Both ripple marks and sand waves are well developed along this contact. The latter clearly illustrate the manner of formation of cross-bedding, characteristic of the sand below. The size and geometry of these sand waves are similar to those measured in modern streams. The cross-bedding is similar to that in ancient sediments of supposed alluvial origin. Logs, sticks, and other organic debris, as well as pebbles, show strong preferred orientation, here shown to be related to the cross-bedding and therefore to the current direction. A decrease in the average thickness of the cross-bedded units upward in the section is interpreted as indicating a decrease in current strength. This is in line with the history of the point bar.

APPARENT SUPERSATURATION OF CALCIUM CARBONATE IN SEA WATER

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Sodium carbonate, 0.01M, was added to sea water at constant rates, and the resultant pH was recorded continuously. The plot of pH vs the number of ml of sodium carbonate added exhibits two "breaks," representing first the precipitation of calcite, and second, aragonite.

The liquid phase of the system was defined to include $NaCO_3^-$, $MgCO_3^0$ (Garrels *et al.*, 1959), $MgHCO_3^+$, $CaHCO_3^+$, $CaCO_3^0$ (Greenwald, 1941), as well as the more commonly defined ions (Ca^{++}, Mg^{++}, $CO_3^=$, etc.); the activity product, $(Ca^{++})(CO_3^=)$, at 23°C., was determined to be 2.0×10^{-8} and 3.0×10^{-8} for calcite and aragonite from the "breaks" data for natural sea water and 5.0×10^{-9} and 7.0×10^{-9} for artificial sea water.

Smith's data (1940) for the Bahama Banks was recalculated to include the above ions. Ion activity products, $(Ca^{++})(CO_3^=)$, for the ocean data ($0.76–1.8 \times 10^{-6}$) were lower than the aragonite product (for natural sea water) of this study but higher than the recalculated solubility product of Smith's (1941) study (4.9×10^{-9} at 30°C.) and higher than the aragonite product for artificial sea water of this study. Recalculated activity products for calcite in sea water give 2.6×10^{-9} at 25°C. and 3.9×10^{-9} at 5°C.

UPPER DEVONIAN PALEOCURRENTS IN THE CENTRAL APPALACHIAN MOUNTAINS

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Primary structures and their directional properties were studied in the Upper Devonian marine sedimentary rocks of New York, Pennsylvania, Maryland, Virginia, and West Virginia. The distal, Flyschlike Portage facies contains abundant, well-developed sole markings (chiefly groove casts and flute casts), small-scale cross-lamination, current ripple marks, and oriented clasts. Sole markings are also present in the near-shore Chemung facies, but they are not so well developed or so abundant.

The marine paleocurrent pattern was determined by measurement of approximately 2400 current structures. A very regular and persistent east-to-west current trend existed throughout this area during most of Late Devonian time. There is a gradual upward change in the current directions to the northwest. Measurement of 900 cross-bedding dip directions in the Catskill "red beds" revealed a mean-current azimuth of 292°. Thus the nonmarine paleoslope to the northwest had developed before deposition of the Pocono (Mississippian) sandstone began.

Paleocurrent data indicate a linear source region which extended for several hundred miles along the present Atlantic seaboard. Sediment was not derived from one central distributary but from many outlets along the upland front. As basin filling proceeded an oscillating shore line migrated westward, and the sedimentary strike changed from north-south to approximately N. 30° E.

TECTONIC SIGNIFICANCE OF THE PHASE CHANGE: PLAGIOCLASE → JADEITE + QUARTZ

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Plagioclase has been replaced by jadeite, lawsonite, and quartz in an unusually large area of 60 square miles in Franciscan wackes and volcanic greenstones at Pacheco Pass, California. Several lines of evidence suggest that the California jadeite assemblage probably formed from an unusual combination of rapid increase in load pressure by subsidence and burial (and tectonic pressure?), plus delayed heating of the rocks.

Goldschmidt's theory that the Mohorovicic discontinuity represents the nearly isochemical phase change from basalt to eclogite is currently much discussed. This transformation compares to replacement of plagioclase by jadeite, lawsonite, and quartz in that both represent alteration of plagi-

oclase to denser minerals. The occurrence together at Pacheco Pass of jadeitized rocks and eclogite (in minor amounts) suggests that their P-T stability fields may overlap, although eclogite probably forms typically at somewhat higher temperatures and pressures than does jadeite. Eclogite may be uncommon at Pacheco Pass because basalt was uncommon in the original section, rather than because the P-T conditions were not favorable for eclogite formation.

The widespread jadeite alteration and the shallow depth of the oceanic M discontinuity foster speculation on whether, through depositional and tectonic subsidence, Franciscan rocks underwent an M discontinuity phase change. If they did, the occurrence of jadeite in similar rocks in Japan, Celebes, and elsewhere in California has special tectonic significance. Possible compositional differences in rocks at the M discontinuity would explain some puzzling seismic data.

COARSE FACIES OF THE BELT SERIES, SOUTHWESTERN MONTANA

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Coarse sandstones and conglomerates occur as a marginal facies of the Belt series along an east-west zone from the north end of Bridger Range to the Butte Highlands in southwestern Montana. These grade northward, by intertonguing, into the finer-grained, basal Greyson, Newland, and Chamberlain formations.

The coarse and intertonguing finer-grained detrital materials are arkosic, locally approaching graywacke, and noteworthy in that cross-bedding, ripple marks, rounding of grains, and other features generally typical of extensive reworking are virtually absent. Freshness of feldspars and dominantly coarse texture are also indicative of mechanical weathering, rapid erosion, short transport, rapid burial, and little reworking. Graded bedding and intraformational slump structures are common. Carbonate rocks are few except in tongues of finer-grained materials.

Locally, the sequence is 6000 feet thick and possibly thicker where the base is not now exposed. The contact between the coarse facies and pre-Beltian metamorphic rock is exposed locally between Milligen Canyon and the Mayflower mining area.

Geometric relations and details of stratigraphy in the Bridger Range suggest fault control for the southern margin of the depositional basin, and relations along other parts of the basin suggest a similar control. Steep flexuring may have formed parts of the topographic high.

The coarse material was derived from a steep, barren, metamorphic source to the south, was dumped by torrential streams into the rapidly subsiding marginal part of the Beltian sea, and came to rest with little reworking. Turbidity currents shifted much of the debris toward deeper water.

LIVING THINGS—MAJOR PRODUCERS OF PETROLEUM HYDROCARBONS

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Interest in hydrocarbon compositions is warranted by the important role they play in crude-oil formation. Hydrocarbons, as unusually stable organic substances and the principal constituents of petroleum, may provide the least altered and most significant evidence on how petroleum was formed. Naturally occurring hydrocarbons have been analyzed by mass and absorption spectrographic and chromatographic methods. Structures and distributions of hydrocarbons in nature reveal that petroleum is probably formed in a simple, traceable way.

The dominance of n-paraffins, terpanes, steranes, and related compounds in the saturate hydrocarbon fractions of living things, sediments, and crude oils prove, that plants and animals make, and petroleum contains, these hydrocarbons. Only a biogenic origin can feasibly explain the common prominence of certain structurally identical compounds in the hydrocarbons from organisms, sediments, and crude oils.

AUTHIGENIC PROCESSES IN THE LOWER CRETACEOUS BLAIRMORE GROUP, ALBERTA, CANADA

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Authigenic minerals from Lower Cretaceous sedimentary rocks of Alberta can be divided into silicates and carbonates. Typical silicate assemblages are quartz-kaolinite in rocks low in volcanic detritus, chlorite-quartz-kaolinite-montmorillonite in rocks containing an intermediate amount of volcanic detritus, and chlorite-quartz-zeolite in rocks containing abundant volcanic detritus. Thus, the various authigenic silicates can be interpreted as phases in a multicomponent system; the composition of a particular authigenic assemblage correlates with the composition of the associated detrital constituents. The distribution of the different authigenic silicates is also partly controlled by the inferred depositional environment of the strata as a whole.

Unlike the silicates, authigenic carbonates (largely calcite) occur in highly variable proportions in these rocks, regardless of the composition of the detrital fraction or the depositional environment.

Textural criteria indicate that chlorite, if present, is the first authigenic mineral to form and is distributed homogeneously within the area of a thin section. The remaining interstitial space of many samples is divided among irregular silicate- or carbonate-impregnated zones, forming mutually exclusive areas up to several square centimeters in dimension. Calcite is the last in a particular sequence of minerals to form, but where abundant it appears to have precipitated early, inhibiting the formation of authigenic silicates.

Thus, authigenic processes in these rocks are interpreted as a normal sequence of silicate cementation that can be interrupted at different stages by the introduction of carbonate-bearing solutions from outside the immediate locus of mineralization.

CONCEPT OF STATE OF DRAINAGE SYSTEMS

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Analysis of land forms as physical systems is profitable only if system limits are so defined that mass and energy contents are measurable. Limits proposed by Strahler (1952) permit this for integrated drainage basins. Drainage systems gain energy mainly by water input (precipitation, groundwater discharge), entrenchment of the basin mouth, and solar irradiation; they lose energy by evapotranspiration, ground-water recharge, heat radiation, and discharge of water, rock debris, dissolved load, and heat through the basin mouth. Energy transformations are summarized by equation (1): $E_o + E_d = E_i + \Delta E$; E_o, E_i are mechanical-energy output and input, ΔE is change in system energy, E_d is dissipative energy, unavailable to erosion.

Concept of state of a drainage system embraces (1) degree of topographic maturity, expressed by basin hypsometric properties, and (2) energetic state, expressed by intensive properties that reflect content of mechanical energy per unit area. Strahler's hypothesis that mature drainage basins are homeostatic systems in near-steady condition unifies the two notions. Both topographic texture and ruggedness are needed to indicate the energetic state of a near-steady system. An equation of state must relate these intensive properties to each other and to extensive properties and hold stochastically for all mature basins. Equation (2) does this: $n = kLD/R_r^b$; n is number of channel segments, L channel length, R_r ruggedness, D drainage density. Regression analysis shows $k \simeq 0.8$, $b \simeq \frac{1}{4}$.

GRAIN PROPERTIES AND PETROFABRICS IN GLACIER ICE, NORTH ICE CAP, NORTHWEST GREENLAND

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Oriented thin sections of ice from North Ice Cap, Greenland, were analyzed for texture and crystallographic fabric. Grains averaged 1–3 cm and ranged from 1 mm to 8 cm in diameter. Shapes of most grains were very irregular, but many grains were elongated parallel to folia and dirt bands in the ice; some grain boundaries coincided with bubble and/or dirt bands. These relations suggest that stresses may cause some failures by fracture rather than by shear within the ice.

Most petrofabric diagrams show one, two, or three strongly developed preferred-orientation directions for crystals; several show partially developed girdles extending in various directions from maxima. Strongest orientation was noted in samples from actively flowing ice and weakest in samples from recently superimposed ice. In most diagrams, there are two maxima, axes which lie near a plane dipping in the same direction as the foliation and intersecting it at an angle near but less than 90°, not unlike the orientation of flow-fracture surfaces with respect to stratal boundaries in a series of folded competent and incompetent rock layers. Basal gliding planes in ice crystals were not quite parallel to folia boundaries in the ice examined.

Evidence from ice studies at North Ice Cap shows that fabric and foliation attitudes change quickly with changes in direction and duration of motion and that changes in fabric tend to occur somewhat sooner than changes in foliation.

SYNTHESIS OF EPIDOTE AND ITS APPARENT P-T STABILITY CURVE

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Iron-aluminum epidotes have been synthesized hydrothermally in the pressure range of 3–8 kb. Starting material consisted of SiO_2 glass, $Ca(OH)_2$, $Al(OH)_3$, and Fe_2O_3. The results indicate that an apparent P-T stability curve passes through 650° C. ± 10° and 4 kb. The curve, extending to at least 5.5 kb, has a positive slope of 17.8 ± 2.8 kb per degree.

The reaction products on the low-pressure, high-temperature side of the curve, to 5.5 kb, are anorthite, grossularite-andradite, corundum, and water. Natural epidotes decomposed into the same assemblage in the same pressure range but only at temperatures 100° C. or more above the apparent P-T stability curve. The coexistence of prehnite and epidote at 8 kb and 860° C. suggests a different epidote-forming reaction, perhaps prehnite + corundum = epidote + anorthite + water, or grossularite + anorthite + water = epidote + prehnite.

At water-vapor pressures of 3 and 4 kb, and temperatures higher than 525° C., the initial reaction products are anorthite, garnet, and corundum, but epidote forms in increasing amounts as the length of the run is increased. Owing to the initial formation of the anorthite-garnet-corundum assemblage, 6 weeks at 3 kb and 3 weeks at 4 kb were necessary to obtain sufficient epidote for positive identification.

The synthesized epidotes were positively identified by their optical and X-ray properties, but their small grain size and the slight deviation of d spacings from those of natural epidotes preclude an accurate determination of their iron content by optical and X-ray methods.

URANIUM, LEAD, AND SULFUR ISOTOPIC DATA AND THE ORIGIN OF THE COLORADO PLATEAU URANIUM ORES

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The uranium-lead isotopic ages of the Colorado Plateau uranium ores show considerable variation. The correct explanation of these differences is related to the geochemical origin and history of these deposits. The two foremost theories which attempt to explain the data are based on lead loss or incorporation of old original radiogenic lead. The writer concludes that the hypothesis based on the incorporation of old radiogenic lead is improbable.

In no case do the uranium-lead isotopic ages exceed the stratigraphic age of the host rock. Recent loss of lead can be established in the Lisbon Valley area. New uranium, lead, and lead-isotope analyses of uranium ores from the Todilto limestone, Grants, New Mexico, and from the Tertiary volcanic rocks of Marysvale, Utah, have been made.

In most areas syngenetic or diagenetic uranium accumulation at low temperature in conjunction with lead loss at some later time is believed to be the best explanation for the presently available uranium, lead, and sulfur analytical data.

MASSIVE SULFIDE DEPOSITS IN EUGEOSYNCLINAL BELTS

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Massive pyrite deposits occur exclusively within eugeosynclines and are associated with volcanic and sedimentary rocks of the spilitic sequence. These deposits are in marked contrast to the massive lead-zinc-copper deposits of miogeosynclinal shelf zones.

Pyritic deposits were formed during most geologic periods from the Precambrian to Recent and may be separated into three varieties based on the primary lithologic environment: (1) the volcanic type, wholly within volcanic pyroclastic rocks or at the facies change of sedimentary rocks and pyroclastics (Noranda, Quebec, and Bathurst, New Brunswick); (2) the sedimentary type, occurring within sedimentary rocks stratigraphically far removed from volcanism (Sullivan, British Columbia, and Ducktown, Tennessee); (3) the ultramafic-mafic type, intimately associated with gabbros, norites, or peridotites, within crystalline rocks or adjacent volcanic rocks and sedimentary rocks (Frood-Stobie, Sudbury, Ontario, and Opemiska, Quebec).

This classification of sulfide deposits based on the lithology of the host rock suggests that they formed during volcanism and sedimentation and before folding, intrusion, and metamorphism. The massive sulfide deposits in Japan, which are of late Tertiary and Recent age, formed before orogenesis. These recent deposits are genetically related to concentrations of H_2S gas. Massive sulfide deposits are currently forming on Hokkaido by the action of ferrous sulfate on banded elemental sulfur beds. Pliocene deposits on Honshu appear to have formed by the localization of H_2S in stratigraphic traps and diagenetic folds.

All upper Cenozoic massive sulfide deposits are of the volcanic type but lack the superimposed orogenic and metamorphic features of their more ancient counterparts.

KIMZEYITE, A ZIRCONIUM GARNET FROM MAGNET COVE, ARKANSAS

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Kimzeyite, $Ca_3(Zr, Ti, Mg, Fe'', Nb)_2(Al, Fe''', Si)_3O_{12}$, is a new type of garnet occurring as dodecahedrons modified by trapezohedron at Magnet Cove, Arkansas, in a carbonatite with abundant

apatite, monticellite, calcite, perovskite (dysanalyte), magnetite, and minor biotite, pyrite, and vesuvianite. It is dark brown, H about 7, isotropic, insoluble in acids, infusible before the blowpipe, D = 4.0, n = 1.94. The three strongest X-ray-powder-pattern lines with intensities as measured are 1.667 (10), 2.539 (9), 2.79 (8); the unit-cell constant is 12.46 Å. Microchemical analysis gave (in per cent) CaO 29.8, ZrO_2 29.9, Ti_2O_3 5.0, MgO 0.5, FeO 0.8, Nb_2O_5 1.0, Al_2O_3 11.0, Fe_2O_3 13.4, SiO_2 9.6, sum 101.0, which computes to $Ca_{3.11}(Zr^{+4}_{1.43}\ Ti^{+3}_{0.40}\ Mg^{+2}_{0.07}\ Fe^{+3}_{0.07}\ Nb^{+5}_{0.05})\ (Al^{+3}_{1.36}\ Fe^{+3}_{0.98}\ Si^{+4}_{0.94})\ O_{12.00}$. Basically, this is $Ca_4Zr_2(Al_2Si)O_{12}$ with Ti replacing Zr and Fe replacing Al. Zirconium has been found in other garnets (schorlomite from Magnet Cove, melanite from Kaiserstuhl, Germany, and titanian andradite from Oka, Quebec) in quantity up to several per cent, but in none of these is it a major constituent. Kimzeyite is named in honor of the Kimzey family, long known in connection with Magnet Cove mineralogy.

SPHENE-FLECKED DIORITE FROM MAINE

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Granitic rocks containing small white flecks in which the felsic minerals of the rock are unaccompanied by the mafic minerals, each fleck containing an ophitically intergrown crystal of sphene in its center, have been described from several areas in Europe and have been variously interpreted. A diorite on Baldpate Mountain, Oxford County, Maine, contains about 20 per cent such flecks, each about 3–5 mm in diameter. Comparison with experimental data in the system albite-anorthite-sphene indicates that the composition and abundance of the flecks are those that would be attained by the liquid during a late stage in the equilibrium crystallization of a dioritic magma. Each fleck probably represents a droplet of liquid separated by some disturbance of the crystal-liquid slurry. The sphene was originally distributed throughout the fleck but was reorganized into the central part of the fleck during cooling of the diorite.

USE OF ENGINEERING GEOLOGY IN THE COLORADO DEPARTMENT OF HIGHWAYS

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The use of engineering geology in the Colorado Department of Highways is now emerging as a recognized adjunct to modern highway design and construction. Since the inception of the engineering-geology program in July 1958, the staff has been increased from one to three members, with a corresponding rise in duties and responsibilities.

Originally, the engineering-geology program consisted of supervision of drilling and exploration for bridge footings. In addition, the program now includes: locating suitable sources of road-building material, investigating potential landslide areas prior to construction activities, investigating and making recommendations for safe, economical back slopes in excavations based on rock type, structure, and depth of weathering, investigating proposed tunnel sites, and determining sources of ground water in cuts and excavations and methods of draining wet areas.

PECULIARITIES OF SULFIDE CRYSTAL STRUCTURES

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A sulfide crystal structure is conveniently described as comprising two substructures: that of the large anions and that of the small cations. The former is based on a face-centered cubic lattice, with a = ca. 5.5Å. The cation substructure has a larger, noncubic cell, except in the high-temperature

form, where the metals are disordered. They order on cooling; the polymorphic form obtained depends on the rate of cooling (quenching in the laboratory produces a metastable form not found in nature). Such factors as physical nature of the starting material, presence of a magnetic field, can also be expected to have an effect. Twinning is universal in all but the highest-temperature form. The anion substructure is not affected by twinning: the twin elements are those symmetry elements of the cubic anion substructure that are not symmetry elements of the noncubic cation substructure. The resulting twins may simulate single crystals and produce typical diffraction effects ("twin absences"). Various twin symmetries can be obtained. Such twins are characteristically transformation twins and imply the existence of an original high-temperature form; they possess twin elements other than twofold twin axes and twin planes.

EROSION RATES ON HEBGEN EARTHQUAKE SCARPS, MONTANA

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The earthquake at Hebgen Lake, Montana, on August 17, 1959, created geomorphic features which, since the date of origin is known, can be quantitatively studied as they are reduced by erosion and mass wasting. Two major fault scarps with vertical faces 1–30 feet high were formed. After 1 year the scarp has retreated with a general reduction of vertical face. In some cases, where retreat has been up a steep ground slope, the vertical face has been increased in height.

Retreat of the scarps has been by gravity; cracks form in arcuate shape, and these blocks then fall from the face. Movement results in either a tilting forward of blocks or a slip downslope with blocks still essentially vertical. In some places this results in total obscurity of the scarp front.

Falls occurred where scarps crossed stream valleys. Cabin Creek falls, although in unconsolidated material, withstood erosion well until excessive spring runoff reduced it to a rapids. Red Canyon Creek, with less volume, retains a falls with a steep rapids below. The falls on Whits Lake Creek, a small intermittent stream, has not retreated, nor has it been lowered.

Measurement of rate of retreat of these features indicates that the spectacular results of the earthquake at Hebgen Lake may soon disappear.

CRYSTAL STRUCTURE OF FAIRFIELDITE, $Ca_2(Mn, Fe)(PO_4)_2 \cdot 2H_2O$

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Comparison of the crystallographic data for the triclinic mineral fairfieldite, $Ca_2(Mn'', Fe'')(PO_4)_2 \cdot 2H_2O$, with those of the chemically analogous monoclinic minerals brandtite, $Ca_2Mn(AsO_4)_2 \cdot 2H_2O$, and kroehnkite, $Na_2Cu(SO_4)_2 \cdot 2H_2O$, indicates that a possible structural relationship exists between the triclinic and monoclinic members of the $A_2B(XO_4)_2 \cdot 2H_2O$-type minerals. Cell constants for fairfieldite (present study) are compared with those for brandtite and kroehnkite (from the literature):

	Fairfieldite $P\bar{1}$	*Brandtite* $P2_1/c$	*Kroehnkite* $P2_1/c$
a	5.80 Å	5.66 Å	5.79 Å
b	6.57	12.83	12.61
c	5.48	5.66	5.49
α	102° 26′		
β	107° 39′	99° 30′	108° 30′
γ	90° 35′		
Z	1	2	2

A crystal-structure analysis has now been carried out on fairfieldite; it confirms the structural relation with the previously determined structures of brandtite and kroehnkite.

The structure of fairfieldite was solved by two-dimensional Patterson and electron-density projections on planes normal to [001] and [100], using 70 *hkO* and 276 *Okl* reflections. In the fairfieldite structure the Mn atoms occupy the centers of octahedra formed by four oxygen atoms and two water molecules. Each Mn octahedron has one oxygen atom in common with each of four PO_4 tetrahedra. These octahedra form infinite chains of composition $[Mn(PO_4)_2 \cdot 2H_2O]_n^{-4n}$ parallel to the c axis. The chains are held together by Ca ions, co-ordinated by six oxygen atoms and a water molecule.

Other triclinic minerals of the $A_2B(XO_4)_2 \cdot 2H_2O$ type, including messelite, $Ca_2(Fe, Mg)(PO_4)_2 \cdot 2\frac{1}{2}H_2O$ (?), collinsite, $Ca_2(Mg, Fe)(PO_4)_2 \cdot 2H_2O$, and β-roselite, $Ca_2Co(AsO_4)_2 \cdot 2H_2O$, may be structurally related to the corresponding monoclinic members simply by halving the b axis and eliminating the glide plane and screw axis in each monoclinic structure.

STRUCTURE OF THE CENTRAL CHAMA PLATFORM, NORTHERN RIO ARRIBA COUNTY, NEW MEXICO*

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The Chama platform is an area of low structural relief except for anticlinal zones of uplift within it of less than 500 feet of structural relief. The platform is divided into two parts by the Brazos flaw, a west-trending zone of structural dislocation: the southern part is broad and gently deformed with north-trending folds and faults; the northern part is more highly deformed with northwest-trending folds and fault zones.

East of the platform structures turn sharply up to the Brazos uplift with as much as 5000 feet of structural relief. North of the Brazos flaw the north-trending uplift is broken by northwest-trending faults that produce structurally high salients southwest of each major fault. South of the flaw, the rim continues south without any salients for more than 15 miles.

West of the platform, the Archuleta anticlinorium separates the Chama platform from the San Juan basin to the west. North of the Brazos flaw, the anticlinorium consists of northwest-trending belts of folds. South of the flaw, it is marked by a single north-trending belt of tight anticlines that, farther south, steps westward to the Gallina uplift.

The observed structures are principally Laramide (pre-Blanco basin or San Jose Eocene) and secondarily late Cenozoic that have been superposed on upper Paleozoic and Precambrian structure. Major faults in the basement appear in the upper Cretaceous rocks as long, narrow folds and faults of decreased throw or as disharmonic asymmetrical anticlines with crests on the upthrown side of the faults.

FUNCTIONAL RELATIONS EXPRESSING THE EQUILIBRIUM DISTRIBUTION OF IRON AND MAGNESIUM AMONG CERTAIN METAMORPHIC MINERALS

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The class of heterogeneous equilibria involving ion exchange between certain metamorphic minerals has been examined from the viewpoint of various solid-solution models. The models used are as follows: actinolite, Ca-pyroxene, and orthopyroxene—ideal; cummingtonite—regular.

The closest fits to empirical data on coexisting minerals are provided by the following functions derived for isothermal, isobaric conditions:

$$\text{actinolite-Ca-pyroxene: } Xact = XCa\text{-}px \quad (1)$$

$$\text{actinolite-cummingtonite: } Xact = 1.80Xcum/[1.80Xcum + (1\text{-}Xcum)\exp 0.40(1\text{–}2Xcum)] \quad (2)$$

$$\text{Ca-pyroxene-orthopyroxene: } XCa\text{-}px = 1.82Xor\text{-}px/(1 + 1.82Xor\text{-}px - Xor\text{-}px) \quad (3)$$

Here the X's refer to the atomic ratio $Mg/(Mg + Fe^{2+})$ in the minerals indicated by the subscripts.

* Publication authorized by Director, New Mexico Bureau of Mines & Mineral Resources, Socorro, N. M.

Because of relations between functions (1) and (2) an additional function identical to (2) can be derived for the association Ca-pyroxene-cummingtonite. Empirical evidence supports this conclusion for the observed range in composition. Similarly, the following function for coexisting orthopyroxene and cummingtonite may be derived from (1), (2), and (3).

$$\text{orthopyroxene-cummingtonite: } X_{or\text{-}px} = 0.989X_{cum} / [0.989X_{cum} + (1-X_{cum})\exp 0.40(1-2X_{cum})] \quad (4)$$

Relation (4) is also confirmed by the limited amount of data available.

The constants of these functions contain the temperature and pressure coefficients which, considering analytical errors, appear to be essentially constant in the range amphibolite to granulite facies. The analytical error also appears to conceal the effect of limited variations in other components. These characteristics result in the functions being essentially invariant with respect to other associated phases.

WESTWARD OVERTURNING AND THRUSTING IN THE FLINT CREEK RANGE, MONTANA

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Belt, Paleozoic, and Mesozoic rocks which have undergone Laramide deformation are exposed in the Flint Creek Range, located approximately 30 miles northwest of Butte, Montana. Along the eastern flank of the range folds are consistently overturned toward the west. Imbricate thrusts parallel anticlinical axes. In the central portion of the eastern flank an overturned anticline of Ravalli, Newland, and Missoula rocks has been thrust toward the northwest over lower Paleozoic rocks. Similar structures in Belt and Paleozoic rocks continue at least as far south as Anaconda. In the northern portion of the eastern flank overturned folds plunging to the north become open and upright as they are traced to the north. A few westward overturned folds of Cretaceous rocks exposed in the Clark Fork Valley are peripheral features and become upright at shallow depth.

In the western part of the Flint Creek Range Belt and Paleozoic rocks have been thrust to the east along the Philipsburg fault. Tightly folded autochthonous rocks exposed just east of the Philipsburg fault are overturned to the west, whereas rocks in the thrust plate display open folds with axial planes dipping steeply to the west; this suggests that westward overturning and thrusting preceded eastward thrusting.

The zone of westward thrusting and overturning parallels the probable western border of the Boulder batholith and is believed to represent lateral deformation associated with intrusion of this pluton.

RHENIUM IN PLANT SAMPLES FROM THE COLORADO PLATEAU

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Because some *astragalus* plants were known to absorb appreciable amounts of molybdenum, the ashes of 19 plant samples were analyzed by a spectrographic method for the geochemically associated element rhenium and other trace elements. Data on selenium and uranium were obtained by wet-chemical methods. Rhenium was identified for the first time in plants in 9 of these samples, including 7 of *astragalus*, 1 of *grindelia* and 1 of *eriogonum*. These plants were from uranium mining districts at Thompsons, Utah, and Gypsum Valley, Colorado. The concentrations of rhenium found in the plant ashes range from 50 to 500 ppm.

REFLECTIVITY, CHEMICAL PROPERTIES, AND CLASSIFICATION OF COAL CONSTITUENTS*

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Previous investigators have shown that when reflectivity of vitrains of different "ranks" is plotted against atomic H/C and against volatile matter a clear-cut regression can be demonstrated. Information developed by the author suggests that data from all constituents, regardless of plant origin and degree of metamorphism, can be plotted on essentially the same regressions. Thus, by utilizing reflectance data alone, the atomic H/C and the dry, ash-free volatile matter of any coal can be computed from these standard regressions. There appears to be strong evidence to indicate that variations of low-rank vitrains from the standard progressions are due to calculating H, C, and V. M. to moisture-free basis. Apparently, most moisture in these coals is inherent, bonded moisture and must be included as part of the coal composition which reflectance measures.

Maximum reflectance has normally been utilized for correlation with chemical parameters. In the described study reflectance of randomly oriented particles was determined and a mean (geometric = $\sqrt[3]{R^2_{max} \times R_{min}}$) reflectance thus obtained. Scatter using mean reflectance appears to be no greater than published data on vitrains where maximum reflectance is employed. Because they are not precisely equatable, maximum reflectance data can seldom be compared with mean data. As determination of mean reflectance is amenable to automated data collection, the writer suggests that future reflectance data be so collected.

AUTHIGENIC MUSCOVITE AND CHLORITE IN THE MACCRADY FORMATION

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The Mississippian Maccrady formation consists of a stratigraphically lower red and gray detrital sequence, an upper detrital and carbonate sequence containing anhydrite, and a sequence of evaporitic mudrock, carbonates, anhydrite, and halite. Lower Maccrady rocks contain quartz, feldspar, illite, and chlorite. Illite has poor crystal quality. Chlorite is acid resistant, detrital, and of poor crystal quality. Some rocks contain noncrystalline matter. Upper Maccrady rocks contain quartz, feldspar, muscovite, and chlorite with or without carbonates. Quartz and feldspar are absent from -2 μ fractions. Chlorite is destroyed by dilute HCl, and the treated residue contains detrital chlorite. Crystal quality of muscovite and chlorite varies in different size fractions within the clay grade and in different lithologies. In -1 μ fractions and red mudstones more poorly crystalline varieties occur; in 1–2 μ fractions and gray mudstones more highly crystalline varieties occur. Interbedded carbonates contain poorly crystalline muscovite and chlorite. Saline Maccrady rocks contain some quartz and feldspar, muscovite, chlorite, dolomite (and calcite), anhydrite, and halite. Quartz and feldspar are absent from -2 μ fractions. Muscovite and chlorite have high crystal quality and are more homogeneously distributed in different clay sizes.

The relations suggest authigenic growth of well-crystallized muscovite and chlorite, after lithification, where an excess of silica-deficient clay phase existed in the presence of a saline pore fluid. The muscovite has properties similar to the pure composition. The chlorite is a normal chlorite with b parameter close to that of amesite. The (060) reflection is 1.52 Å and difficult to distinguish from that of muscovite. X-ray diagrams of both muscovite and chlorite show strong reflections from the first five orders, but higher orders are not observed.

* Published with permission of the State Geologist, Indiana Geological Survey.

ORIGIN OF THE OYSTERS

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Many of the more conspicuous features of living oysters are evidently consequences of the adaptive zone in which they now live. The origins of these features have not been illuminated by the fossil record, but newly discovered evidence in the Permian reef complex of Texas indicates that the ancestral forms may have been the pseudomonotids, a family of specialized Pectinacea of byssate and cemented habit. Superficially, these forms closely resemble modern oysters in adaptation, form, hinge, and ligament.

A trend is observed in the Texas pseudomonotids in shortening of the hinge and progressive reduction and disappearance of a juvenile byssate stage followed by ostrean cementation. True oysters are distinguished by loss of the foot and byssus during the prodissoconch stage, cementation by the left valve, and possession of a calcite shell. The last two characteristics apparently were not acquired before early or middle Triassic time, and a fossil record bearing on this transition is unknown. Consequently, the transition from Pseudomonotidae to Ostreidae may have required as much as 20 million years.

GLACIAL LAKES IN LONG ISLAND SOUND

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The Southern New England sounds are marked by three bathymetric basins which were occupied by fresh-water lakes in the Late Wisconsin. At their greatest extent, these lakes were contemporaneous and continuous with other lakes in the area now occupied by metropolitan New York and covered an area of about 4000 square miles. These lakes (earlier suspected by Hollick, Antevs, and Lougee), traced through Long Island, Block Island, and Rhode Island sounds, were formed in a Tertiary subsequent valley, flanked on the south by the Cretaceous of the Long Island-Martha's Vineyard cuesta. With the initial retreat of the ice about 30,000 years B.P., the basins were dammed by the Long Island terminal moraines.

Distortion and over-consolidation of some varved lacustrine sediments indicate the presence of post-Ronkonkoma proglacial lakes, whereas the greatest development of the lakes in the area was post-Harbor Hill, dating about 24,000 years B.P. We propose to call this stage "Glacial Lake Antevs." The lake sequence was terminated by isostatic rebound and the apparent catastrophic breaching of the morainal dam east of Long Island which aided the erosion of Block Island Submarine Canyon.

The warping of the Sangamon (?) Pamlico-Cape May-Gardiners datum from south to north across New Jersey suggests a former marginal bulge, which may be isostatically subsiding, as shown by the anomalous negative behavior of the City of New York tide gauge.

DIFFUSION OF HELIUM THROUGH SEDIMENTARY ROCKS

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Helium is produced by the radioactive decay of the nuclides of certain minerals, and it is commonly assumed that a portion of this helium migrates from its source in the Precambrian through overlying rocks to the atmosphere. In order to evaluate the effect of diffusion control on this migration, a series of mathematical models have been devised to describe a wide range of practical situations. These models range from that for a single, infinite, uniform layer of sediment to that with any given number of differing, finite, uniform layers of sediment. These models are solutions of the one-dimensional

diffusion equation, for which approximate boundary conditions have been constructed by considering the variation with time of both the helium concentration and helium flow at the Precambrian and sediment surfaces. The resultant concentration-distance curves decrease from the Precambrian to the sediment surface, whereas the concentration-time curves for any given point in the sediments all rise to a peak and then decrease with time. The time at which the peak occurs increases with distance from the Precambrian.

STUDY OF MOVEMENT ACROSS THE MARGIN OF AN ICE CAP

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Four traverses were established across a steeply sloping section of the margin of North Cap near Thule, Greenland. These were surveyed in 2 successive years. Distances between control points were determined by taping and by theodolite and Invar subtense bar. Elevations were established by precise leveling.

Movement rates range from 0.1 to 0.5 inch per day. Strain rates average 1 per cent per year on weakly foliated ice and are as high as 5 per cent per year on well-foliated ice. The deformation appears to be the product of over-all plastic yielding aided by differential movement along discrete shear planes. Differential movement is most pronounced in well-foliated dirty ice close to the glacier terminus.

Comparison of ablation from the surface with the surfaceward component of movement shows that this section of the margin is in a state of transition from a steeper slope in the past to a more gentle one in the future; this suggests the decay of an ice cliff.

FACTS OR CONCEPTS: WHICH SHOULD BE EMPHASIZED IN INTRODUCTORY COURSES?

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Experience suggests that courses emphasizing factual material and the memorization process generally are frequently poor foundations for additional work and are likely to be pedestrian or dreary for the student.

A factual basis for developing understanding of concepts is needed, but such understanding is achieved most effectively by emphasizing the processes of inductive and deductive reasoning in lectures, discussions, laboratories, and examinations. Specific techniques for accomplishing this end include: (1) emphasis on examination questions beginning with "why" and "how" rather than questions beginning with "what;" (2) inclusion of numerous examples of deductive and inductive reasoning in lecture; (3) the answering of student questions with other questions, and (4) posing questions at the end of lectures for subsequent thought.

INTER- AND INTRACOLONY VARIATION IN *ACINOPHYLLUM*

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Analysis of inter- and intracolony variation in cylindrical-phaceloid rugose corals offers the possibility of differentiating between genetic and environmental variation, and between colonies with one and more than one genotype. Number of major septa and corallite diameter have been statistically analyzed in 62 colonies of *Acinophyllum simcoense* and 8 colonies of *A. stramineum* from the Middle Devonian Onondaga limestone in New York. Intracolony variation (V_n = 1.9 to 8.7; V_d = 5.8 to

15.9, in 32 colonies of *A. simcoense*) is lower than intercolony variation ($V_n = 11.3$; $V_d = 22.5$) in both characters, even in groups of colonies from lithologically uniform stratigraphic units. On the basis of available data one can speculate that septal-number variation was genetically limited in the normal colony. Bimodal septal-number distribution in a few colonies with high coefficients of variation ($V_n = 6.4$ to 8.7) suggests that these may be intergrowths of two or more colonies with differing septal numbers.

Intercolony variation is related to lithology and is greatest in groups of colonies from the stratigraphic units which represent the most favorable environment as indicated by abundance and variety of associated corals. Intercolony coefficients of variation in septal number and diameter are greatest ($V_n = 9.9$; $V_d = 19.1$) in the reef facies where *Acinophyllum* is associated with abundant and varied tabulate and solitary and colonial rugose corals. Intercolony variation is least ($V_n = 3.3$; $V_d = 7.8$) in a localized coral bed, formed by *A. simcoense* and one other species, in which no other fossils have been found.

CONTAMINATION STUDIES IN RADIOCARBON DATING

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Radiocarbon ages are reliable if samples are uncontaminated with secondary carbon. Contamination can be a serious problem, however, especially for very old samples. Experiments aimed at recognizing and then removing contamination have been carried out on all the major types of radiocarbon samples.

Recognition of contamination is based on age discrepancies between fractions of a single sample or between two stratigraphically equivalent samples of different type. For 35 samples of wood, peat, charcoal, and soil, the extracted humic acids have generally had the same age as the residual material. Exceptions are two Alaskan permafrost soils which showed younger humic acids. Of three charred bones, two showed age differences between carbonate and organic fractions; the carbonate was younger. For two old shells, inner and outer fractions showed no detectable radiocarbon and hence dated as >38,000. Shells associated with very old wood (>40,000 years) gave a finite age.

Wood was artificially contaminated in a beaker of contemporary humic acids and in swamp muck (*in situ*); humic-acid removal was successful in the latter case, and partially successful in the former.

Samples exposed to $C^{14}O_2$ gas at 150° C. were negligibly contaminated in the case of wood, charcoal, and bone organic, but the activity of bone carbonate was increased greatly.

Wood, charcoal, and peat—when properly treated—give reliable ages to the sensitivity limit of present measuring equipment (40,000 years); most shells give reliable ages up to about 20,000 years, perhaps even beyond if several fractions are dated; bones give almost wholly unreliable ages.

ORGANIC MATTER IN SHALLOW MARINE BAYS

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Shallow marine bays of the Central Texas coast have high annual productivity and rapid deposition. A 2-year survey of organic carbon in various environments of these bays and measurements of the rate at which organic matter was decomposed revealed that organic matter produced during the warm summer was decomposed during winter when productivity decreased. Particulate organic matter incorporated in the sediments had already undergone considerable alteration and continued to be decomposed. Decomposition data provided validity to the assumption that much organic matter is in a humus state and not readily available to bacteria. Organic-carbon content of particulate material collected from the bay water by a 0.4-micron MF was about 0.5 to 1 ppm by weight basis. Organic content of surface sediments ranged from 3.5 per cent in beds of benthic plants to 1.5 per

cent in blue-green mats and 0.05 per cent in washed beach sands. Profiles of organic carbon across a barrier island revealed the identity of the island. Large pieces of organic matter, such as a fish buried in sediment, rapidly decomposed and created a localized anaerobic zone where pH first decreased and later increased. Diurnal pH measurements in surface and subsurface sediments indicated that productivity occurred as deep as 1 cm in sediments. Uptake and release of carbon dioxide by metabolism and photosynthesis in the sediments produced marked daily pH change. Gases produced during decomposition were: methane, nitrogen, hydrogen sulfide, and carbon dioxide. Oxygen and hydrogen were consumed.

POSSIBLE GEOCHEMICAL SYNTHESIS OF PURINES ON THE PRIMITIVE EARTH

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Amino acids (Miller and Urey, 1959), amino-acid amides (Oró *et al.*, 1959), and polypeptides (Oró and Guidry, 1960) can be synthesized under conditions assumed for the primitive earth.

The most important purine, adenine (Oró, in press), may be synthesized by heating at moderate temperatures (70°C.) an aqueous solution of ammonium cyanide. In addition to adenine, several other compounds which are intermediates or by-products in the synthesis of purines have been identified by chromatographic techniques. These compounds include glycine, 4-amino-5-imidazolecarboxamide, and 4-amino-5-imidazolecarboxamidine.

The formation of the purine ring, and in particular of adenine, at moderate temperatures from the simple and reducing compound ammonium cyanide, supports the ideas of Oparin, Urey, and others about the essentially reducing conditions of the primitive earth environment when the first biochemical compounds were formed.

POWDER X-RAY METHOD FOR DETERMINATION OF (Ab + An) CONTENT OF MICROCLINE

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A $20\bar{1}$ X-ray-determination curve for triclinic K-rich feldspar has been established over the composition range Or_{100} to $Or_{70}Ab_{30}$.

$\Delta 2\theta$ ($20\bar{1}$ *feldspar*—101 $KBrO_3$) *Cu radiation*

	Microcline	*Sanidine*
Or_{100}	.77 °2θ	.74 °2θ
Or_{90}	.87	.84
Or_{80}	.96	.94
Or_{70}	1.06	1.04

Nearly pure K feldspar, which corresponds to "maximum microcline" and contains less than 1 weight per cent Rb feldspar and Ca feldspar and less than 0.2 weight per cent Na feldspar, was produced by ion-exchange reaction between natural microcline perthite and molten KCl at 900° C. Na-bearing feldspars were formed by dry homogenization at 1050° C. for 2 days of weighed mixtures of this K feldspar and a natural low albite.

The departure from monoclinic symmetry as measured by $\Delta 2\theta$ (131–$13\bar{1}$) of these alkali feldspars varies according to the Na-feldspar content; the nearly pure K feldspar shows the greatest departure ($\Delta 2\theta = .77°$), and that which contains 30 weight per cent Na feldspar shows the least departure ($\Delta 2\theta = .61°$). The lower "triclinicity" of the Na-bearing feldspars is not believed to reflect an intermediate structural state between microcline and sanidine, since the Na-bearing feldspars can be

converted to nearly pure K feldspar corresponding to maximum microcline by ion exchange with molten KCl. The change in $\Delta 2\theta$ (131–$\bar{1}31$) can be attributed strictly to the partial substitution of K by Na.

The composition of the "maximum microcline" phase in approximately 30 natural microcline perthites has been determined by this X-ray method. The average Ab + An content found is 4 weight per cent, and the range is 0.5 to 6 weight per cent.

NONEOLIAN ORIGIN FOR SILTS OF THE ARCTIC SLOPE, ALASKA

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The marked summit accordance of the Northern Foothills section of the Arctic Slope has been attributed to structure and composite erosion, but this does not account for the unconsolidated materials underlying this surface.

A calcareous silt deposit, up to 130 feet thick, underlies the accordant summit surface in a belt just south of the Coastal Plain. This belt is more than 250 miles long and 10–30 miles wide. The deposit shows a grade-size distribution comparable to materials usually assigned to an eolian origin except for a somewhat higher content (8.0 per cent) of sand (>0.074 mm). On fresh surfaces the stratification is inconspicuous except where locally emphasized by fine organic material. The silt is uniform laterally and vertically and overlies fine calcareous sand. In one location a similar calcareous sand overlies the silt. The present low organic content is considered to be initial, since local concentrations of organic matter indicate that permafrost conditions prevented extensive oxidation of the silts. The slow decay of organic matter in the Arctic should lead to abundant organic matter in eolian deposits.

The presence of marine fossils in the upper portion of alluvial sequences lying upon the eroded Cretaceous bedrock implies a marine-fluviatile origin for the silts. They are interpreted as having been deposited during a Pleistocene transgression into the Northern Foothills section. The advancing sea caused alluviation of the valleys. It eventually covered the area, and the depositional plain now recognized in the summit accordance was formed.

NOTES ON THE CORRELATION OF DENSITY AND COMPOSITION IN MIX CRYSTALS

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Bloss (1952) derived an expression for the mol per cent of component A,

$$N_a = \frac{100}{1 + K\dfrac{(\rho_a - \rho)}{(\rho - \rho_b)}},$$

where molar volumes are additive, and A is "the end member with the larger molecular weight" or "the denser end member." These designations may be contradictory, as in the systems HgSe–HgTe and NaCl–KCl. The relation is not invalidated where the designations are contradictory, since K is Va/Vb, and its value is changed to the reciprocal if A and B are interchanged. No statements about the density or molecular weight of A (or B) are needed, but the definition of K must be consistent with the subscripts.

Additivity of molar volumes is not equivalent to additivity of cell dimensions (Zen, 1956). Fujii (1960), commenting on Bloss and Zen, derived expressions for the position, eNi, and magnitude, $\Delta\rho e$, of the extreme departure from linear variation of density with molar composition in binary solutions; molar volumes are additive. The expression $\Delta\rho e$ is nil only if $Va = Vb$, as Bloss noted.

If density is stated as a function of composition, and cell-edge lengths of end members are stated in cubic mix crystals, comparable expressions are obtained for three ideal cases:

Densities additive (linear variation):

$$\rho = \frac{M}{V} = N_a \frac{M_a}{a_{0_a}^3} + (1 - N_a) \frac{M_b}{a_{0_b}^3} \tag{1}$$

$$N_a = \frac{\rho - \rho_b}{\rho_a - \rho_b} \tag{1a}$$

Cell volumes additive (Bloss' assumption, Fujii's "ideal solid solution"):

$$\rho = \frac{N_a M_a + (1 - N_a) M_b}{N_a (a_{0_a})^3 + (1 - N_a)(a_{0_b})^3} \tag{2}$$

$$N_a = \frac{1}{1 + K \dfrac{\rho_a - \rho}{\rho - \rho_b}} \tag{2a}$$

Cell-edge lengths additive ("Vegard's law"):

$$\rho = \frac{N_a M_a + (1 - N_a) M_b}{(N_a a_{0_a} + (1 - N_a) a_{0_b})^3} \tag{3}$$

where ρ is density, N is mol fraction, M is cell weight, a_0 is length of cell edge, and subscripts refer to end members.

Bloss derived the expression 2a. If K is unity it may be converted to (1a) by algebraic operations. "Vegard's law" is the linear variation of a_0 with mol per cent. This corresponds to linear variation with weight per cent only if mol weights of end members are equal. Labelling a line on a plot of spacings against weight per cent, "Vegard's law" (Yoder and Keith, 1951), is erroneous.

STRATIGRAPHIC RANGE AND SIGNIFICANCE OF THE CAMBRIAN AGNOSTID GENUS *GLYPTAGNOSTUS*

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Glyptagnostus is represented in the United States by two species, *G. reticulatus* (Angelin) and a new species. Two subspecies can be recognized within *G. reticulatus*: *G. reticulatus reticulatus* (Angelin) is found only in association with *Aphelaspis* and the acrotretid brachiopod *Angulotreta*; *G. reticulatus angelini* (Resser), a slightly older form, is associated with aphelaspinid trilobites and the acrotretid brachiopod *Opisthotreta*. The new species has been found only with species of *Cedaria*.

Comparison of faunal successions in the Snake Range and at McGill, Nevada, provides strong evidence that beds with *G. reticulatus angelini* and aphelaspinid trilobites are contemporaneous with beds assigned to the *Crepicephalus* zone in central United States. Time-transgressive biostratigraphic units are necessary to describe the faunal relationships.

G. reticulatus reticulatus was originally described from the *Olenus* zone of the standard Upper Cambrian section of Sweden. The occurrence of this subspecies and the closely related subspecies *G. reticulatus angelini* in beds representing the *Aphelaspis* and *Crepicephalus* zones respectively of the American Cambrian section provides an important tie point for intercontinental correlation of Upper Cambrian rocks.

STABLE CARBON-ISOTOPE STUDIES OF CRUDE OILS AND THEIR PORPHYRIN AGGREGATES

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The origin of porphyrin aggregates in petroleum is one of the intriguing problems of petroleum geochemistry. Previous laboratory data have indicated that the metal-porphyrin complexes originated during the sedimentation phase and the period of diagenesis before the petroleum moved from its source bed.

Development of new methods for the purification of petroleum porphyrin aggregates and the isotope-ratio mass spectrometer allows comparison of C^{13}/C^{12} ratios of petroleums and their porphyrin aggregates with chemically similar substances in contemporary organisms.

Isotopic fractionation in plant processes suggests that porphyrins from the organic source material, or produced by bacterial degradation of carbohydrates prior to or during deposition, should have C^{13}/C^{12} ratios about 5‰ larger than the petroleum hydrocarbon.

Several petroleums and highly purified porphyrin aggregates separated from them were analyzed for their C^{13}/C^{12} ratios to test these predictions. The C^{13}/C^{12} ratios of all the relatively pure porphyrin aggregates are 4–5‰ greater than the C^{13}/C^{12} ratios of the crude oils from which they were extracted. The differences in the C^{13}/C^{12} ratios are proportional to the purities of the samples from any given oil.

These results indicate that the porphyrin aggregates were not formed as a secondary process from petroleum oils. Rather, the porphyrins arose either from original organic material or original material plus bacterial contributions during the destruction of the nonlipid fractions during deposition. In either case these data indicate that the porphyrins from these petroleums were present during the formation and diagenesis of the oil.

BASE METALS IN BIOTITES ASSOCIATED WITH ORE DEPOSITS

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The copper, lead, and zinc content of biotites from monzonitic stocks in the Basin and Range Province is being investigated. The biotites are being analyzed spectrochemically with an Applied Research Laboratory 1.5-meter, 24,400-line-per-inch grating spectrograph. Indium is the internal standard. The precision of the analytical method is approximately 17 per cent for copper, 17 per cent for lead, and 31 per cent for zinc as determined from 12 replicate analyses.

Quantitative data have been compiled for the Robinson (Ely) district, Nevada, and the Bingham district, Utah. The arithmetic means of the base-metal concentrations and their standard deviations from the means follow.

Bingham district, Utah	
Bingham stock (9 samples)	1900 ± 1900 ppm Cu
	11 ± 4 ppm Pb
	63 ± 23 ppm Zn
Last Chance stock (4 samples)	110 ± 26 ppm Cu
	48 ± 17 ppm Pb
	160 ± 32 ppm Zn
Robinson district, Nevada	
Liberty and Veteran pits (5 samples)	4600 ± 3100 ppm Cu
	10 ± 6 ppm Pb
	140 ± 93 ppm Zn

The Bingham and Last Chance stocks in the Bingham district belong to different base-metal concentration populations. The Robinson district is similar to the Bingham stock in lead content of biotite but different in copper and zinc concentrations.

The high copper concentrations probably represent not only biotite lattice substitutions but also inclusions of chalcopyrite.

UNDERGRADUATE RESEARCH TRAINING IN FIELD GEOLOGY

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An undergraduate field-geology research program with a small group of students has been carried out for the past two summers in Montana with support from the National Science Foundation. The students were academically outstanding junior and senior geology majors who previously had taken at least 20 hours of geology.

The summer program consisted of 4 weeks of field-course instruction in mapping techniques, followed by 6 weeks of independent field work by the students in pairs. Areas were changed at the end of 3 weeks, so that each student was responsible for mapping an individual area.

This program was considerably more than a summer field course. Each student mapped an area which had not been mapped previously. Some were inspired to go on in geologic research on the graduate level. The areas mapped fitted into the over-all research projects of the authors. The students realized that they had contributed to the ultimate goal and were not just carrying out a mapping exercise.

Research experience for undergraduates not only serves to inspire good students but also allows the selection of those undergraduates who have true research potential and should therefore be expected to do well in graduate school.

MINERALOGY AND PETROLOGY OF UPPER MISSISSIPPIAN CARBONATE ROCKS OF THE CUMBERLAND PLATEAU IN TENNESSEE

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The mineral assemblages of upper Mississippian carbonate rocks of the Cumberland Plateau in Tennessee, with only minor exceptions, obey the Gibbs phase rule. Compositional variation of the expandable chloritic minerals lies between the composition of vermiculite and that of corrensite, the ordered end member, and is consistent with the topologic requirements of the phase diagram of the system MgO–CaO–Al_2O_3–SiO_2–CO_2–H_2O. SiO_2 is present in excess, and CO_2 and H_2O are considered to be perfectly mobile. The minerals must have formed an equilibrium assemblage at some time in the diagenetic history of the rock. Lithologies are clearly related to mineral assemblages; lithologic associations determined from stratigraphic relationships are the same as those determined from mineral assemblages. The lithologies and original bulk-chemical composition of the sediments were determined by the depositional environment. The mineral assemblages developed in response to the chemical composition. These assemblages may be the true equilibrium assemblages or may be metastable assemblages resulting from structural changes in the dolomite.

TECHNIQUES OF GEOLOGIC ILLUSTRATION

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Drawings are a powerful means of recording observations and communicating concepts. They have been used from the beginnings of research in earth science. As an educational device, art forms are a powerful stimulant to initiative and thought.

A recent search for source material on art in geology leads to the conclusions that (1) geologic thought has been abundantly expressed by in situ drawings; (2) this means of expression translates the intricate variations of the earth into simple terms of fundamental geologic principles; (3) this means of expression is personalized from the viewpoint of the scientist highly trained in a variety of disciplines; (4) crude as this expression may be in some cases, it is a vital stimulant to interest and curiosity. Many art forms of geology as portrayed by earth scientists repose in notebooks in the archives of academies, institutions, and government bureaus. Would not an orderly selection and compilation of these original data surmount lingual ignorance and reach an almost universal audience?

REEF CREEK DETACHMENT FAULT IN NORTHWESTERN WYOMING

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The Reef Creek detachment fault is a nearly horizontal fault on which blocks of Madison limestone (Mississippian) 50–5000 feet long have been transported. The blocks are scattered over an 80-square-mile area 12–25 miles southeast of the northeast corner of Yellowstone Park. Many of these blocks rest on early acid volcanic rocks of Eocene age. Subsequent major horizontal movement of several miles on the Heart Mountain detachment fault scattered the blocks still farther and separated the eastern part of the once continuous early acid volcanic rocks into many scattered masses. The relation of the Reef Creek fault to the South Fork fault 25 miles southeastward has not been determined, but the two are closely related in time and have many similarities.

The Reef Creek and Heart Mountain detachment faults are in part the result of gravity movement, but gravity alone is inadequate for the low slope involved. Along the western border of the Bighorn Basin vertical displacement of 20,000 feet, mostly during early Tertiary time, undoubtedly was accompanied by many earthquakes. Extrusion of the volcanic rocks, closely associated in time with the fault movements, can be presumed to have been preceded and accompanied by repeated tremors. It is suggested that the shaking motion of innumerable earthquakes, combined with the constant force of gravity, caused the detached fault blocks to move great horizontal distances on a slope of a few degrees.

STRUCTURE AND STRATIGRAPHY OF THE COSSAYUNA AREA, NEW YORK

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The Cossayuna area lines in the southern part of Washington County, about 40 miles northeast of Albany, New York. Most of the area is underlain by shaly rocks of the Taconic thrust plate, but, in the western part, the edge of the thrust plate is exposed. The autochthonous sequence, Upper Cambrian? and Lower and Middle Ordovician carbonates overlain unconformably by upper Middle Ordovician black shale, is exposed below the thrust plate.

The Taconic sequence, Early and Late Cambrian and Early and Middle Ordovician in age, is

tightly folded with axial planes dipping east. Folding took place during thrusting, for fold axes are cut by two tear faults on the western edge of the exposed thrust plate. The thrusting occurred after middle Trenton because a *Cryptolithus tesselatus* was collected immediately below the thrust plate. The Taconic sequence was emplaced in its present position early in the time of Snake Hill deposition, for the autochthonous Snake Hill shale is thin below the thrust where best exposed.

Normal faults, some of which cut the thrust plate and some of which are overlain by the thrust plate, provide a basis for the interpretation that the autochthonous Snake Hill shale to the west of the exposed Taconic thrust plate partially fills a graben and may be covering a considerable amount of the Taconic thrust plate.

LAND SUBSIDENCE DUE TO WITHDRAWAL OF FLUIDS. PART 2

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The present paper describes areas in Japan in which subsidence has occurred because of fluid withdrawal, steps being taken in California at Wilmington toward controlling subsidence, and results of recent measurements of compaction in the San Joaquin Valley.

In Japan subsidence occurs in four harbor areas. At Tokyo, Nagoya, and Osaka, subsidence reportedly is due to ground-water withdrawal for industrial use. Maximum subsidence at Tokyo is about 2 m and at Osaka about 3 m. In each area, the decline of artesian head has caused compaction of fine-grained clayey sediments.

At Niigata, subsidence is caused by removal of saline ground water containing dissolved gas, from wells as deep as 900 m. Subsidence has accelerated sharply since 1955 and by 1959 was at a maximum rate of 50 cm per year. Compaction is being measured in 12 wells ranging in depth from 20 to 1190 m.

At Wilmington, California, repressuring of the oil zones with saline ground water was begun in 1958 and stopped subsidence locally within 3 months. Results suggest that subsidence can be controlled effectively by repressuring.

In the San Joaquin Valley, compaction recorders operated on wells of several depths are furnishing evidence that compaction is occurring chiefly in the confined aquifer system. Total measured compaction is about equal to the land subsidence, which indicates that subsidence can be attributed almost wholly to fluid withdrawal.

ENDEMIC PACIFIC COAST CRETACEOUS FAUNAL SEQUENCES

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Pacific Coast Cretaceous gastropod-pelecypod faunas from Albian to Maestrichtian age, inclusive, show remarkable uniformity in composition and the presence of a number of persistent genera ranging through much or all of later Cretaceous time. Each of these genera is represented by a sequence of species commonly showing close relationship within the genus and suggesting membership in a common genetic line. Temporal range for individual species is ordinarily of stage magnitude or less but is in some cases longer. These lineages are of practical value in correlation and of theoretical value in estimating rates of evolution in Cretaceous Mollusca; but determination of species is difficult, must be arbitrary in some cases, and usually requires abundant specimens for precise identification. The sequence as a whole suggests that the late Cretaceous faunas of the Pacific Coast were endemic to the region for more than half of the Cretaceous period, and that a few elements persisted locally into the Paleocene. Typical generic groups are illustrated and described.

PENNSYLVANIAN CLASTIC SEDIMENTATION IN THE ILLINOIS BASIN

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Pennsylvanian sediments of the Illinois Basin cover an area of 55,000 square miles, have a maximum thickness of 3000 feet and are approximately 60 per cent shale, 35 per cent sandstone, 4 per cent limestone, and 1 per cent coal. Underclays, coals, limestones, and black shales have the greatest lateral persistence, sandstones the least. The sandstones, as a result of their marked variations in thickness and the erosion of stratigraphic markers, are the disruptive elements of the sequence and impart a pronounced streakiness to most facies maps.

Although petrologic differences exist, the Pennsylvanian sandstones of the basin consist of only two types: sheet and channel. Sheet-type sandstones are thinner, finer-grained, have less cross-bedding, and are more widespread than channel-type sandstones. Channel-type sandstones have disconformable basal contacts, whereas those of the sheet-type sandstones are conformable. Although channel-type sandstones vary widely in scale, meandering and anastomosing patterns are typical. Such patterns recur throughout the Pennsylvanian section, can be traced across the basin, and are generally oriented to the south and southwest.

Conclusions based on sandstone studies integrate well with other evidence and emphasize the strong unity and organization of Pennsylvanian sedimentation in the basin. Pennsylvanian sedimentation is described in terms of basin geometry, character of basin fill, arrangement of the fill within the basin, and tectonic setting. Change in these factors produces variants and transitions to other types of sedimentation.

COMPACTION IN CALCILUTITES

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The amount of compaction observable in many relatively pure calcilutites (clay- and silt-sized particles) is minor compared to that in shales. Although the often cited laboratory experiments of Terzaghi (1940) showed a similarity in compaction between lime mud and clay, the amount of compaction evident in many calcilutites appears more analogous to that of sandstone or siltstone.

Many authors have interpreted the absence of crushing of delicate fossils as an indication of minor compaction of lime muds in the formation of calcilutites (Weller, 1959). Supporting data are the scarcity of drag or penetration effects where rigid clasts or fossils occur in a calcilutite matrix; and the general similarity in fabric of sediment within a noncompacted cavity, such as a shell, and sediment of the enclosing matrix. Larger-scale evidence is provided by observations of attitude, thickness, lithology, and geopetal fabrics of calcilutites which are laterally adjacent to other rocks for which minor compaction can be demonstrated. Examples of these relationships occur in biohermal facies, such as those of the Mississippian of western United States.

The minor compaction of many calcilutites requires formation of a rigid fabric prior to accumulation of much overburden. The mechanisms producing ridigity are not well established. The physical parameters, such as packing, of the initial sediment are important. Early cementation is considered of major significance. Possibly whisker crystallization assists in creating compaction-resisting strength early in diagenesis.

CRYSTAL STRUCTURE OF CAHNITE, $Ca_2BAsO_4(OH)_4$

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Cahnite is one of the few crystals assigned to crystal class $\bar{4}$. A precession study showed that its diffraction symbol is $4/mI-/-$, which contains space groups $I4$, $I\bar{4}$, and $I4m$. Because of the known

$\bar{4}$ morphology, it must be assigned to space group $I\bar{4}$, which it then shares with only one other mineral, nagyagite. The unit cell, whose dimensions are a = 7.11 Å, c = 6.20 Å, contains two formula weights of $Ca_2BAsO_4(OH)_4$. The structure was studied with the aid of intensity measurements made with a single-crystal diffractometer. Patterson syntheses were made for projections along the *c*, *a*, and [110] directions. The atomic numbers of the atoms are in the ratio As:Ca:O:B = 33:20:8:5, so that the Patterson peaks are dominated by the atom pairs containing arsenic as one member of the pair. Since there are only two arsenic atoms in a body-centered cell, one arsenic can be arbitrarily assigned to the origin. Then the major peaks of the Patterson syntheses are at locations of atoms in the structure. The structure, determined approximately in this manner, was refined by least squares and by two-dimensional difference maps.

The structure consists of As tetrahedrally surrounded by O_1 at a distance of 1.67 Å and B tetrahedrally surrounded by O_2 at a distance of 1.47 Å. Ca_1 is surrounded by four O_1 at a distance of 2.44 Å, and by four O_3 at 2.55 Å; Ca_2 is surrounded by four O_1 at 2.38 Å and four O_2 at 2.55 Å.

LEWIS THRUST SHEET IN THE SOUTHEASTERN CORDILLERA OF CANADA*

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The fault that defines the base of the Lewis thrust sheet has a maximum stratigraphic throw of 25,000 to 30,000 feet. It has been traced for more than 200 miles along the tectonic strike of the Rocky Mountains of Alberta and Montana and has been recognized in fensters and boreholes over an interval of 25 miles across the tectonic strike.

The orientation and mutual relationships of folds and minor thrust faults within the thrust sheet indicate that a relative eastward displacement of the more northerly Flathead-Highrock Range salient has been superimposed on structures originating under relative northeastward displacement of the Clark Range salient.

The stratigraphic path followed by the Lewis thrust fault indicates that: (1) the fault selectively parallels specific stratigraphic zones over large areas; (2) transverse, tearlike "steps" in the stratigraphic position of the fault have resulted in the development of transverse monoclines in the thrust sheet; (3) pre-existing broad folds have been truncated locally; (4) the maximum displacement along the fault is greater than 40 miles.

The displacement of the Lewis thrust sheet resulted in substantial shortening and thickening of the sedimentary veneer above the crystalline basement of the eastern Cordillera and in a significant addition to the thickness of the M crust in the eastern Rocky Mountains.

RELATION OF GEOLOGIC SOURCE, DEPTH OF WELL, AND TOPOGRAPHIC LOCATION TO THE YIELD OF WELLS IN THE EASTERN COAL FIELD, KENTUCKY

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Determining the yield of wells from data collected during a ground-water reconnaissance of a rural area where pumping equipment is primitive or not available for controlled pumping tests may present a real problem, especially where the yield of wells is controlled by several natural variables. The Eastern Coal Field of Kentucky, a rough, hilly region underlain by shale, sandstone, and coal of Pennsylvanian age, is a typical example. Reliable pumpage data are difficult to obtain, and the yields of wells vary widely because they are affected by geologic source, depth of well, and topographic location.

The information on well yields obtained during a reconnaissance of the area included reports of bailing tests and water usage by well owners, data on pumping equipment and depth to water, and

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the results of a few pumping tests. On the basis of known principles of ground-water occurrence in the area, this information was placed in four categories based on geology and topographic position. Each category in turn was divided into seven depth zones, and minimum, median, and maximum values for yield were computed for each zone. When this information was adjusted and placed in tabular form, it was possible to determine within certain limits the probable yield of a well drilled to any depth at any place in the Eastern Coal Field.

FRINGE-ZONE ALTERATION IN CARBONATE ROCKS, NORTH TINTIC MINING DISTRICT, UTAH

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Roughly zoned hydrothermal alteration occurs in the folded and faulted Paleozoic carbonate rocks near the north fringe of the Tintic mining district. At least five types of alteration are recognized: dolomitic, argillic, jasperoid, calcitic, and productive. This resembles the alteration described by Lovering *et al.* for the East Tintic area.

Hydrothermal dolomite is the earliest and most widespread stage and decreases with increasing distance northward. Argillic alteration is least abundant and of local occurrence. A jasperoid stage of alteration occurs as replacements of carbonate rock, is less abundant than the hydrothermal dolomite, and becomes sporadic northeastward. Calcitic alteration includes the replacement and/or open space filling in carbonate rock by red hematite-impregnated calcite. Northward, orifices resembling former hot-spring pipes are partially to completely filled by this and other calcite types and aragonite. The calcitic stage mainly postdates the jasperoid stage. It lies north of the jasperoid masses and is more abundant. Iron, lead, zinc, and probable silver sulfides, minor manganese, and reported bismuth and gold characterize the last or productive stage. This is closely associated with the calcitic stage, although the gold and bismuth occur near jasperoid rock. Except for the argillic stage the productive alteration has the least known quantity of introduced materials. Although exact time dating of the hydrothermal alteration stages is not possible in this area, the sequence appears to be dolomitic, argillic, jasperoid, calcitic, and productive in a crudely zoned distribution pattern north of the main Tintic district.

OLIGOCENE MARINE—NONMARINE RELATIONS, COASTAL VENTURA BASIN, CALIFORNIA

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Transition from the terrestrial environment of the Sespe formation to the marine environment of the Alegria formation is represented by a gradual facies change. The area of interfingering is characterized by 12 major lithologic units which consist chiefly of conglomerate, sandstone, siltstone, and mudstone. These lithic units lose identity within short distances both laterally and vertically.

The Alegria may be subdivided into two general facies: (1) brackish-lagoonal, characterized by oyster-bearing mudstone and siltstone; (2) littoral-shallow neritic, consisting of coarse- to medium-grained fossiliferous sandstone and conglomerate.

Petrographically there is no distinction between Sespe and Alegria sandstones. Point counts indicate that the sandstone is epidote-bearing (up to 5 per cent) lithic arkose (19–37 per cent feldspar) with an argillaceous matrix and/or calcareous or ferruginous cement. The average mean diameter, average mean deviation, and mean skewness of the Sespe and Alegria sandstones differ only slightly from one another. Compositions of the conglomerate and sandstone indicate a source area of igneous, metamorphic, and sedimentary rocks of probable Jurassic, Cretaceous, and Eocene age.

Red beds in both formations are considered to be primary. The red pigment originated in a warm

humid source area and was preserved at the site of deposition. The climate was warm and sufficiently moist to support palms and ferns.

RESULTS OF A GEOLOGY CURRICULUM AND STANDARDS STUDY, UNITED STATES AND CANADIAN SCHOOLS

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The Curriculum and Standards Committee of the National Association of Geology Teachers circulated a comprehensive questionnaire to the 250 schools granting geology degrees in the summer and fall of 1959; returns were received from 226 departments of geology-geophysics.

A check list of courses indicating the degree level at which each course is normally offered for credit revealed considerable variation. Regarding foreign languages, 68 per cent of the departments require some at the baccalaureate level and 50 per cent at the master's. Credit requirement for the baccalaureate range from 23 to 84 quarter credits and 17 to 31 semester credits, for the master's, 18–50 quarter credits and 12–36 semester credits, for the doctorate, 30–96 for both quarter or semester credits. Among departments offering the master's (55.3 per cent of schools responding), 13.6 per cent require no dissertation. Mineralogy was considered the most fundamental course for the baccalaureate, followed by physical and historical, structural, invertebrate paleontology, petrology, field geology, stratigraphy, economic, geomorphology, sedimentation, and summer field camp; 25 other courses were listed.

Scientific writing is required by 24 per cent of the departments; drafting by 35 per cent; minimum mathematics requirement in calculus by 40 per cent and in trigonometry by 21 per cent. Qualifying examinations for the master's are not required by 30 per cent of the departments; a teaching-load minimum is required in 50 per cent of the departments; sabbatical leaves are not offered in 28 per cent of the departments.

QUANTITATIVE GEOPHYSICS APPLIED TO METALLIC-MINERAL-PROPERTY (*e.g.*, IRON-ORE) EVALUATION

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A survey of contemporary Russian and American literature concerning exploration geophysics indicates that quantitative interpretations can be achieved for conductive-mineral deposits from co-ordinated magnetic, electromagnetic, and/or gravimetric surveys. The use of electromagnetic devices demonstrates the feasibility of estimating ore grade for certain buried conductive-mineral assemblages—*e.g.*, copper and nickel sulfides, iron ore. Analyses of this nature appear to be helpful in determining the economic potential of mineral properties, either at the outset of an exploration-development program or as an aid to establishing present value.

Electromagnetic and magnetic field studies were conducted over tabular deposits of copper sulfides, nickel sulfides, magnetite, and magnetite-hematite. A primary field was created by use of a long grounded wire, up to 5000 feet in length. Variances in amplitude and phase of vertical component of the electromagnetic field were determined by a Wien-type bridge connected to two horizontal 3-foot coils. Magnetic data were obtained through use of an Askania Schmidt-type magnetometer, readable to three gammas.

The electromagnetic technique allowed interpretation of the spatial distribution of conductivity and the magnetic technique that of permeability, from which grade (*e.g.*, per cent Fe) and tonnage estimates were thereby deduced.

DISTRIBUTION OF MINOR ELEMENTS IN SOME IGNEOUS ROCKS OF CENTRAL AND NORTHWESTERN ARIZONA

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Two hundred and twenty-three rock samples were collected along 3 roughly linear traverses from 7 major intrusive bodies, several smaller plutons and dikes, and from 1 dominantly migmatitic complex.

The ferromagnesian phases (chiefly biotite) were separated from each sample and analyzed spectrochemically for Pb, Sn, Ga, Ni, Co, Cr, Cu, Zn, Mo, V, and Ag, and by X-ray fluorescence for Ti, Fe, Mn, Ca, K, Cu, and Zn. The bulk-rock samples also were analyzed by X-ray fluorescence for Si, Ti, Fe, Mn, Ca, K, Cr, and Zn.

The analytical results, coupled with petrographic and field data, indicate: (1) the minor-element content of the ferromagnesian phases within a given pluton is relatively uniform, and no systematic trends are apparent; (2) a significant difference between plutons with respect to the minor-element content of the ferromagnesian phases; (3) the differences in content of certain minor elements is as great between plutons of like rock type as between different rock types in the range diorite to granite; (4) variations in the content of other minor elements more sensitive to rock type (Zn, Ga, V, Pb) are superimposed on variations between plutons; (5) the Fe/Ti and Fe/Mn ratios in the bulk rock appear to be unaffected by differences in rock type; (6) virtually all the Cu and Zn in the bulk rock are accounted for in the ferromagnesian, oxide, and sulfide phases; (7) areas of known copper mineralization are reflected in anomalously high copper contents of the associated plutonic bodies.

RELATION OF THE McGEE GLACIAL STAGE TO THE LATE CENOZOIC HISTORY OF THE SIERRA NEVADA

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Morainal material on the high upland slopes of McGee Mountain in east-central California was designated by Blackwelder as representing the McGee glacial stage. These deposits have not been investigated in detail since. They are important because four glaciations of the eastern Sierra Nevada can be recognized in this area, and the relationships of one to the other can be confidently established.

The McGee till, which is the oldest and is a possible equivalent of the Kansan, has been uplifted a minimum of about 4000 feet by faulting which followed deposition. Deep canyons were excavated after this uplift of the range, and these have been the sites of three later glacial advances, each of smaller extent than its predecessor.

The presence of the four tills in the marginal fault zone of the eastern Sierra Nevada makes this a critical area for determining the tectonic, volcanic, and erosional history of the range. A provisional chronology appears to be as follows:

Local event	*Sierran glacial succession*	*Presumed equivalent, central U.S.*
Minor faulting and probably continuing uplift	Recent	Recent
Valley glaciation	Tahoe-Tioga	Wisconsin
Eruption of rhyolitic pumice and obsidian; continued uplift of 1000 ± feet		Sangamon
Canyon deepening; valley glaciation	Sherwin	Illinoian

Uplift of 3000 ± feet; canyon cutting		Yarmouth
Extensive upland glaciation	McGee	Kansan
Uplift of eastern Sierra Nevada by 2,500 ± feet	Early Pleistocene	Early Pleistocene
Erosion of broad upland surface; eruption of basalt	Late Pliocene (?)	Late Pliocene (?)

CORRELATION OF PENNSYLVANIAN STRATA ON THE BASIS OF NORTHWESTERN ARKANSAS GONIATITES

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The type localities for the formations of the Pennsylvanian Morrow group and immediately older and younger strata are located in Washington County in northwestern Arkansas. Correlation of these rocks with those of southeastern Oklahoma and elsewhere is ostensibly based on goniatite cephalopod assemblages, despite the fact that only four forms have been reported from Washington County. Two of these fossils are from post-Morrow strata, one is erroneously identified, and the remaining Morrow form is not recognized from elsewhere.

Nine described genera and some probably new forms have been recovered from local Morrow and post-Morrow deposits which are readily distinguishable with respect to stratigraphy. Insofar as the goniatite assemblages of southeastern Oklahoma can be compared with those of northwestern Arkansas, the Winslow of earlier writers is not equivalent to the Atoka but is older. The southeastern Oklahoma Morrowan appears to fit between the Brentwood and Kessler members of the Bloyd formation. The Prairie Grove member of the Hale formation is probably correlative with the Rhoda Creek formation and the Mississippian Pitkin formation with the Delaware Creek member of the Caney shale.

THICKNESS OF THE EARTH'S CRUST AS RELATED TO TECTONISM, VULCANISM, AND MINERALIZATION IN COLORADO

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An Airy-Heiskanen anomaly map of Colorado, prepared by applying isostatic reductions to gravity data supplied by Ralph C. Holmer, is interpreted in terms of crustal thicknesses. The crustal model selected for computations was one having material of density 2.67 gm/cm^3, underlain by material of density 3.27 gm/cm^3.

Minimal thickness values result over most mountain ranges and plateau areas in Colorado. For example, thicknesses as low as 35 km are found over the Front Range and the Uncompahgre uplift. This figure agrees with that obtained by Tatel and Tuve by seismic methods in the Colorado Plateau (Arizona, New Mexico, Utah).

Maximum inferred thicknesses, however, are found in areas where intrusive or extrusive igneous rocks are present. Examples are the Colorado Mineral Belt and the San Juan volcanic rocks. In both these areas, thicknesses of about 50 km are found.

The conclusions drawn are: (1) the crust in Colorado is warped and perhaps split in distinct blocks; (2) warping probably occurred during Precambrian; (3) mountain ranges are perhaps genetically related to the upwarps; and (4) igneous activity and mineralization may have been a response to melting of the sialic rocks which were pushed deep into the mantle during warping.

STRATIGRAPHY OF THE THREE FORKS SHALE IN SOUTHWESTERN MONTANA

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The Three Forks shale of Late Devonian and Early Mississippian age has been studied in detail within a 25-mile radius of the type section near Logan, Montana. Within this area it ranges in thickness from 150 to 300 feet and presents a complex array of facies, whose age and stratigraphic relationships have caused considerable controversy. Three members have been recognized, and there is stratigraphic evidence of interfingering between them.

The lower member consists predominantly of gray limestone breccia, laminated gray limestone, and red silty shale. This sequence is unfossiliferous, and its depositional environment is interpreted as restricted marine because it interfingers with marine limestone and contains evidence of evaporites.

The middle member is predominantly green shale which becomes silty and abundantly fossiliferous toward the top. The unit is interpreted as a normal marine sequence which was deposited near or below wave base. Clymenid cephalopods and leiorhynchid, cyrtospiriferid, and athyrid brachiopods are considered the more important groups in its fauna.

The upper member, the Sappington sandstone, consists of siltstone and sandstone which weathers orange and locally contains thin beds of calcareous, brown or black shale. It is interpreted as a shallow marine deposit, the muds having formed in shallow areas between the sandy shores of islands and current-swept channels. Contrary to several previous reports, the brachiopod *Cyrtospirifer* has been found associated with *Syringothyris* in the basal beds of the Sappington. The *Syringothyris* fauna of earlier writers is considered a facies fauna which favored a sandy bottom.

CALCITE CRYSTALLOGRAPHY AND THE STUDY OF ECHINOID PHYLOGENY

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Data on the calcite crystallography of coronal plates from a wide range of fossil and Recent echinoids indicate that the preferred orientations of c axes provide a useful tool with which to study echinoid phylogeny. Orientation patterns have been established for 55 fossil species and 66 Recent species. Of the 19 currently accepted echinoid orders, all but three (Bothriocidaroida, Megalopoda, and Pygasteroida) are represented in the present sample.

Most species fall readily into one of two orientation types by having c axes which are either perpendicular or tangent to the plate surface. Important exceptions are found in some cidaroid genera where ambulacral plates have perpendicular c axes and the interambulacral plates have tangential c axes. Ontogenetic variation is extreme in some groups: single individuals of species in the Conulidae, for example, exhibit a progression from one orientation type to the other in a single plate column.

At high taxonomic levels c-axis orientation appears to be controlled. All species studied in the orders Echinocystitoida, Palaechinoida, Echinothurioida, Diadematoida, Hemicidaroida, Phymosomatoida, Clypeasteroida, Holasteroida, Nucleolitoida, Cassiduloida, and Spatangoida have the perpendicular orientation. By contrast, the representatives of the Arbacioida (with one exception) and the Temnopleuroida have the tangential orientation. In the Holectypoida, Echinoida, and Cidaroida, a mixture of orientation types obtains, but uniformity is still present at the family level (except in the Cidaridae). These crystallographic data are applied to several basic problems of evolutionary development of major echinoid groups.

RELATION OF THE PROFILE OF WEATHERING TO MECHANICAL ANALYSES OF LOESS

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Mechanical analyses of the zones of the profile of weathering developed in loess along the Ohio Valley show expectable and significant differences in grain-size distribution. Grain-size distributions for the readily discernible zones of the profile of weathering developed in the youngest and thickest loess, the Peorian, indicate that in the clay-enriched zone (2), below the surficial zone (1), there is 28 weight per cent clay-sized particles, or approximately 3.5 times the weight per cent of clay-sized particles in the oxidized and unleached zone (4), which most closely resembles the unmodified parent material. Analyses indicate about 13 per cent clay-sized particles in the intermediate oxidized and leached zone (3), in contrast to only 8 per cent in the underlying zone (4). As the per cent of clay-sized particles decreases, the per cent of silt increases from approximately 70 in the clay-enriched zone (2) to 90 in the oxidized and unleached zone (4).

In order that local and regional evaluations of grain-size distribution may be made of individual loess deposits, samples analyzed must be derived from the same zones of the profile of weathering. Otherwise, data are useless for comparative evaluation. Difficulties are compounded where several loess deposits, each with a profile of weathering developed in it, are grouped together as members of a single formation or unit; mechanical analyses referable only to the formation or unit without specific designation of zone are essentially meaningless.

PETROFABRIC STUDIES OF AN ICE LAYER FROM A FIRN FOLD NEAR THE BAY OF WHALES, ANTARCTICA

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A petrofabric study of a deformed layer of sedimentary blue ice contained in a firn-ice anticline in the Ross Ice Shelf near the Bay of Whales, Antarctica, shows a moderately strong preferred crystal orientation. When plotted on a Schmidt equal-area net the highest density of *c*-axes is 8–9 per cent per 1 per cent area. The strongest fabric diagram reveals four maxima located respectively at 32°, 27°, 26°, and 21° about the pole of the plane of maximum shear.

The crystal fabric of a small ptygmatic fold from one limb of the anticline suggests that the fold was produced by differential slip along basal glide planes which are essentially orthogonal to the bedding planes of the respective limbs.

GEOLOGY AND HEAVY-MINERAL CONTENT OF PLACER DEPOSITS IN THE ELK CITY REGION, IDAHO

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Stream placer gravel in the Elk City region, Idaho, studied by the Idaho Bureau of Mines and Geology to determine presence or absence of commercial concentrations of detrital heavy minerals, totals 55 million cubic yards, of which 25 million cubic yards has been mined for its gold content. Minable gravels occur in local wide-valley areas of low gradient, connected by narrow-valley areas of high gradient. Average values of 15 samples, in pounds per cubic yard, are: allanite 0.2, monazite 0.15, rutile 0.07, brookite 0.1, sphene 0.1, zircon 0.25, ilmenite 6.9, magnetite 16.8. Brannerite, euxenite, and columbite are present in trace amounts.

Quartzose Tertiary basin deposits cap certain ridges and benches; streams have cut below the bottom(s) of the former basin(s). The outcrop area of these deposits is about 18 square miles, and their average thickness is probably more than 20 yards (volume more than 1×10^8 cubic yards). Average values of four small grab samples, in pounds per cubic yard, are: monazite 1.6, rutile 0.3, brookite 0.3, zircon 1.5. Such concentrations of heavy minerals in the Tertiary deposits, when considered in conjunction with the high quartz content of the deposits, seem to imply rather intense weathering of the erosion surface from which the deposits were derived.

Most of the Elk City region is underlain by biotite gneiss. Data in hand indicate that the major part of the heavy minerals in the placer deposits was derived from the biotite gneiss.

ELECTRON PARAMAGNETIC RESONANCE STUDIES OF THE ORGANIC GEOCHEMISTRY OF STABLE FREE RADICALS

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Paramagnetic materials can absorb energy from a radio-frequency field under the condition $h\nu = g\beta H$ where ν is the frequency, H the intensity of magnetic field, β is the Bohr magneton, and g is the spectroscopic splitting factor ($g = 2.0023$ for free electrons). Using 3.2-cm microwaves and sweeping the magnetic field of about 3000 gauss, we can study the distribution of unpaired electrons or free radicals in materials by observing the character of the electron-paramagnetic-resonance (EPR) absorption of the radio-frequency energy.

A large class of natural organic materials contains free radicals. These include lignin; tannins; oxidized natural phenolic compounds; degraded quinone pigments; humic acids; the peat through anthracite coal sequence; pyrobitumens, the asphaltic portion of petroleum, and chars of most organic matter. A range of free-electron concentration occurs in these materials, but in humic materials their concentration is usually no higher than 10^{19} spins per gram.

The free radicals in asphaltenes are stable from below −196°C. to 600°C. in air as well as in boiling aqua regia, sulfuric acid, nitric acid, hydrofluoric acid, phenyl hydrazine, and sodium in tetrahydrofurane for periods of hours. Coal-free radicals are less s' ble than asphaltenes.

EPR studies of wood fractions confirm Freudenberg's (1959) interpretation of lignin as a free-radical polymer. Lignin per se did not exist in the oak, spruce, pine, redwood, and eucalyptus woods examined. The free radicals which polymerize to form lignin form under conditions of acidic or basic hydrolysis, oxidation, or attack of precursor materials by some fungal enzymes. Freudenberg (1959) suggested that the free radical is a semiquinone.

BEHAVIOR OF SULFUR UNDER MAGMATIC AND HYDROTHERMAL CONDITIONS AND ITS EFFECT ON S^{32}/S^{34} RATIOS

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The writer suggests that the appreciable variation of S^{32}/S^{34} ratios in minerals of sulfide ore deposits of magmatic and hydrothermal origin may be due to processes operating within the ore fluids: (1) polymerizations of metal-sulfur complexes with the screening sulfur ions removed from any complex of higher S^{32}/S^{34} ratios than the ratio of the complex prior to the polymerization stage in question, (2) oxidation of sulfur concomitant with reduction of certain metal ions (such as Cu^{+2}, As^{+5}, Sb^{+5}, and Sn^{+4}) to a lower valence state, where the sulfur ions oxidized are of a lower S^{32}/S^{34} ratio than the ratio of the complex prior to the oxidation in question, (3) probable preferential precipitation at higher temperatures of sulfides with higher S^{32}/S^{34} ratios than the original averages for the ore solutions involved and at lower temperatures of sulfides with lower S^{32}/S^{34} ratios than the

original averages of the ore solutions concerned (analogous to the hydrothermal Leadville dolomite in which O^{18}/O^{16} ratios decrease as the temperature of carbonate emplacement increases), (4) the taking over of sulfur deposited at higher temperatures by sulfides deposited by replacement at lower temperatures (occasionally the reverse), so that S^{32}/S^{34} ratios resulting in the guest minerals will be anomolously high (or low). Examples show how possible combinations of these factors explain many of the wide variations from the norm of 22.13 in natural ores, particularly low-temperature deposits. The correspondence in the isotopic behavior of oxygen in silicon-oxygen complexes in silicate magmas and of sulfur in metal-sulfur complexes in hydrothermal solutions is discussed.

WAVE PROPAGATION IN ROCKS

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The action of a suddenly applied load is not instantaneously transmitted to all parts of the loaded body. Deformations and stresses move through the body with definite and finite velocity, usually several thousand feet per second, in the form of a transient disturbance or wave, which in rocks generally produces marked irrecoverable changes. The progress of the disturbance, its change in intensity, and its change in shape cannot be theoretically described simply or rigorously. Consideration must be given the following: dispersion, changes caused by the varying velocities of the several parts of the disturbance; geometric divergence (and convergence) which affects both the intensity of the disturbance and its shape; and attenuation, extraction of energy from the disturbance by scattering, inelastic deformation, and other complex processes. Dispersion, geometric divergence, and attenuation as a rule radically and quickly modify the shape of a disturbance, and the disturbance thereby loses its original identity. Various rocks differ markedly in dispersive and attenuating properties; velocity of propagation of the disturbance is strongly dependent on state of stress and rock type, and attenuation varies greatly with rock type as well as with frequency.

PALEOZOIC STRUCTURE IN THE GREAT BASIN

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The Great Basin lies atop the Cordilleran geosyncline in Nevada and Utah in an area 475 miles wide and 550 miles long. Two principal parts of the geosyncline are recognized: a western eugeosyncline, characterized by thick volcanic and clastic rocks; and an eastern miogeosyncline, characterized by carbonate rocks and some detrital rocks. The western boundary was mainly a volcanic archipelago; the eastern was the Wyoming-Utah shelf. The geosyncline began to form in late Precambrian time and continued as a single trough until Late Devonian when it was split by the Antler orogenic belt.

The major positive structural elements within the geosyncline during Paleozoic time were: (1) the east-west Uinta-Gold Hill arch in Utah and eastern Nevada, intermittently active in Ordovician and Late Devonian time; (2) the Antler orogenic belt, a zone of acute orogeny in Late Devonian to Early Pennsylvanian time, that extended north-northeast, medially through Nevada—this orogeny culminated in the Roberts Mountains thrust which juxtaposed different Paleozoic facies; (3) related uplifts near the Nevada-Utah line and in western Utah, active during Mississippian and Permian time; and (4) the Sonoma orogeny in western Nevada in late Permian time.

The major negative structural elements superimposed on geosynclinal subsidence were: (1) the Chainman-Diamond Peak trough of Mississippian age in eastern Nevada; (2) the Oquirrh trough of Pennsylvanian and Permian age in western Utah and south-central Idaho; (3) the Pumpernickel-Havallah basin in western Nevada, and (4) the Bird Spring basin, a northeastward-trending trough in southern Nevada; both (3) and (4) received sediments during Pennsylvanian and Permian time.

FLUID ENVIRONMENT OF PETROLEUM

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The fluid environment of petroleum has received relatively little attention. On the premise that most sediments and precursory petroleum constituents in a petroleum province were born in water and henceforth saturated by it, the subsurface fluid system must be recognized as an environmental entity, to be integrated with the geological framework in the evolution of petroleum.

Elementary reasoning on the fluid environment is developed by examining the system for proportionality, differentiation, rhythm, and condensation-diffusion. The writer suggests that the classic stages of petroleum evolution—origin, migration, and accumulation—are an integrated continuum. The structural basin is regarded as an internally differentiated vessel, bounded by the basement and the atmosphere and containing a more or less unified fluid system which occupies about 10 per cent of the bulk volume.

In the transition from petroleum source to accumulation, component proportionalities in the fluid system must change. The constituents of petroleum must be condensed and probably modified in some degree, despite wastage and attenuation. Differentiation of the fluid is required and is believed to occur diagenetically in some proportion to stratigraphic and structural differentiation of the geological framework. Certain natural rhythms may be involved in driving the diagenetic process through the framework.

The writer suggests that fluid differentiation culminates in the trap complex.

DIAMOND-DRILL-HOLE DEVIATION IN THE BLIND RIVER AREA, ONTARIO, CANADA

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More than 700,000 feet of diamond drilling in the Blind River area provides an unrivalled volume of data bearing on many facets of drilling of interest to those involved in an appraisal of ore deposits. One of these facets is diamond-drill-hole deviation.

The data show that most deviation in deep holes (holes deeper than 2000 feet) takes place in the upper part of the hole, although there is some relation between amount of deviation and stratigraphy.

Deviation is caused by the planar elements in rocks but is enhanced or reduced by various drilling techniques. A drill hole in rocks with planar elements should be engineered from the target upward to the collar, in order to take advantage of any natural tendency to deviate.

The location of some deep holes underground permits a qualitative examination of the accuracy of hole surveying using acid tests and tropari bore-hole compass. Use of numerous tropari tests gives a survey sufficiently accurate for mine-planning purposes.

SOME CENOZOIC ROCKS IN SERGIPE, BRAZIL

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A veneer of arkosic sands and gravels of Cenozoic age rests unconformably on Cretaceous and older rocks in the Aracaju area, Brazil. These sands are as much as 60 m thick and extend inland up to 50 km. They were subjected to chemical weathering of lateritic intensity and subsequently overlain by fluvial sediments. The whole sequence has been called "Barreiras" and presumed to be of Pliocene age. The modern drainage was superposed from this presently high-level surface.

The zone of lateritic weathering serves to divide the Cenozoic rocks into two divisions and is a

time-stratigraphic marker which can be correlated from basin to basin throughout northeastern Brazil. Its age is undetermined. A late Pliocene or mid-Pleistocene age appears reasonable.

The prelaterite sediments consist of a basal coarse sand overlain by finer arkosic sands which are now an unusual sediment of sand and clay particles. Thinly bedded silts and clays, thought to represent lagoonal deposits, occur low in the section. Schist and gneiss boulders have weathered to a loose aggregate of quartz, clay minerals, and iron oxide in which the original fabrics are preserved.

During lateritic weathering, iron oxides concentrated in local permeable zones, probably near the water table in poorly drained areas. Silica leached during weathering cemented sand to form "silcrete" near the top of the formation.

APPARENT AGE AND MIGRATION OF URANIUM IN DEPOSITS IN SANDSTONE BASED ON RADIOCHEMICAL ANALYSES

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The results of radiochemical analyses and apparent-age calculations for a series of samples from the Hulett Creek area, Wyoming, were selected to evaluate the use of apparent-age determinations in understanding the migration of uranium in deposits in sandstone. The samples represent oxidized deposits above the water table, oxidized and unoxidized deposits just above and below perched water tables, and unoxidized deposits at least 250 feet below the water table.

The geology, geochemistry, and age results indicate that the original uranium in those deposits now at or above the water table was introduced more than 250,000 years ago. The deposits now above the water table started oxidizing with the lowering of the water table about 80,000 years ago. As the water table moved downward, uranium was leached from the zone of oxidation and reprecipitated below the water level. The oxidation, leaching, and reprecipitation stopped about 10,000 years ago when the water table was lowered below the deposits. The deposits now at the water table started oxidizing about 60,000 years ago. Oxidation, leaching, and reprecipitation of the uranium has continued to the present. The first uranium was introduced into those deposits 250 feet below the water table about 180,000 years ago, and uranium has been accumulating since then.

From radiochemical analyses the probable original grade of leached deposits can be calculated. If the probable grade and the stratigraphy, structure, and geomorphic history of an area are known, the present location of the leached uranium and its possible grade can be estimated.

FOSSIL MAMMALS OF THE HUERFANO FORMATION (EOCENE) OF COLORADO

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Huerfano Basin is a Laramide structure developed between the Sangre de Cristo Mountains (also Laramide) and the Wet Mountains (a rejuvenated Paleozoic structure).

Huerfano beds accumulated during a period of relative inactivity in the Laramide orogeny; fine-grained sedimentary rocks derived from adjacent mountain areas make up most of the formation. Huerfano sedimentation was brought to a close by a pulse of the Laramide orogeny within Huerfano Park.

Huerfano beds contain two fossil mammal faunas; one is of Lostcabinian (late early Eocene) age; the younger fauna represents a substage older than Blacksforkian (early middle Eocene) and younger than Lostcabinian and is characterized by the presence of the following genera: *Hyracotherium*, *Coryphodon*, *Absarokius*, *Cynodontomys*, *Didymictis*, *Eotitanops*, *Diacodexis*, and *Bunophorus* of early Eocene affinity, and *Mesonyx*, *Patriofelis*, *Oödectes*, *Palaeosyops*, *Helaletes*, and *Antiacodon* of middle Eocene affinity.

The Farisita formation, most of which is here considered a lateral equivalent of the Huerfano formation, contains elements of both faunal levels found in the Huerfano formation. The lower faunal assemblage contains *Bunophorus, Coryphodon, Cynodontomys, ?Heptodon, Hyopsodus, Hyracotherium, Lambdotherium* and *Viverravus*; the upper assemblage contains *Bunophorus, Hyracotherium, Metacheiromys,* and *Palaeosyops.*

A vertical interval of less than 200 feet separates localities of the two zones in the Farisita formation. Beds between localities of the two zones in the Huerfano formation are not exposed; the vertical interval between zones is greater than 500 feet.

PRIMARY FLUID INCLUSIONS IN SPHALERITE CRYSTALS FROM THE OH VEIN, CREEDE, COLORADO

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Fluid inclusions in successive zones of large multiply zoned sphalerite crystals were examined in detail as a part of a larger study of a single ore body. (*See* Bethke *et al.* abstract.)

Total salt concentrations in the included fluids were estimated from the depression of the freezing points of approximately 400 inclusions. A special circulating-fluid microscope cell (temperature range −35° to +250° C.) was used, and the fluids were assumed to be water solutions of alkali and alkaline-earth chlorides, as indicated by chemical analyses. Check measurements made by crushing selected single inclusions *in vacuo* for water analysis, followed by leaching and microanalysis for soluble salts, were in good agreement with the freezing-point data.

Systematic variations from 6 to 15 weight per cent total salts were found; earlier zones had the higher concentrations. Filling temperatures also showed a systematic change from ~ 250° C. for earlier zones to ~ 200° C. for later ones, regardless of crystal size. Significant variations in salt compositions and deuterium-hydrogen ratios were also found.

Conclusions: (1) the inclusions are primary and have not lost or gained significant amounts of material since trapping; (2) concentration, composition, and temperature of the fluids changed during the depositional history; (3) inclusions provide a possible tool for recognition of epochs of deposition of sphalerite and for recognition of codeposited minerals; and (4) the writer cannot yet discriminate between possible explanations of the variations found: changes, with time, of the fluid at its source, and mixing of two sources.

PHASE RELATIONS IN THE Mg_2SiO_4-$CaAl_2Si_2O_8$-FeO-Fe_2O_3-SiO_2 SYSTEM AND THEIR BEARING ON CRYSTALLIZATION OF BASALTIC MAGMA

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As one approach to the further understanding of crystallization of basaltic magma, liquidus phase relations were determined in parts of the Mg_2SiO_4–$CaAl_2Si_2O_8$–FeO–Fe_2O_3–SiO_2 system at the oxygen partial pressure of air (0.21 atm.). On the join $CaAl_2Si_2O_8$-iron oxide, magnetite and anorthite are the primary phases. The temperature of the liquidus minimum is 1398° C., and the composition of the liquid is $CaAl_2Si_2O_8$ = 68 per cent, iron oxide = 32 per cent. With the addition of SiO_2 to anorthite-iron oxide mixtures, liquidus temperatures are lowered sufficiently that hematite becomes a primary phase. The lowest liquidus temperature in this system is 1290° C., where hematite, anorthite, and silica are in equilibrium with a liquid having the composition: $CaAl_2Si_2O_8$ = 49 per cent, iron oxide = 11 per cent, SiO_2 = 40 per cent. Three "isobaric invariant" points are found in the Mg_2SiO_4–$CaAl_2Si_2O_8$–FeO–Fe_2O_3–SiO_2 system at 0.21 atm. oxygen pressure. During fractional crystallization of a simplified peridotite or basalt in this system (air atmosphere), the liquid composition moves to

the "invariant" point at which anorthite, magnetite, pyroxene, and silica coexist. This final liquid has the composition: SiO_2 = 57 per cent, Al_2O = 17 per cent, iron oxide = 8 per cent, CaO = 9 per cent, MgO = 9 per cent. During this fractional crystallization at constant oxygen partial pressure, SiO_2 content of the liquid increases as iron-oxide content decreases. Study at the lower oxygen partial pressures characteristic of basalts and andesites is a necessary next step in the investigation of this system.

HIGH-TEMPERATURE X-RAY STUDIES IN THE SYSTEM Cu-S

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Synthetic copper sulfides were X-rayed on a continuously evacuated X-ray-diffractometer heating stage and also in silica capillaries using a Unicam heating camera.

When hexagonal chalcocite (Cu_2S) is heated, it changes to a digenite type of structure at 425° ± 20° C., rather than the 470° C. reported by other workers. Although this structure cannot be quenched to room temperature, inversion is slow near the transition temperature, and this fact accounts for the 20-degree uncertainty. However, the inversion occurs rapidly 50° above or below the transition.

Digenite, which is approximately $Cu_{1.8}S$ at room temperature, exhibits increasing solid solution toward Cu_2S with rising temperature (approximately $Cu_{1.90}S$ at 200° C., $Cu_{1.94}S$ at 300°C.), finally reaching Cu_2S at 425° C.

Below 150° C. the sulfide with the composition $Cu_{1.96}S$ reported by Djurle was observed. The tetragonal form of this phase breaks down on heating to give digenite plus chalcocite. The reaction is reversible and occurs between 100° and 150° C.

As the solid solution between digenite and chalcocite is complete above 420° C. and extensive below that temperature, many ores that contain digenite and chalcocite must have formed from the breakdown of an original digenite solid solution. In the present work, reactions readily occurred to nearly room temperature.

SUBSOLIDUS STUDIES IN THE SYSTEM $CaCO_3$–$MgCO_3$–$FeCO_3$ AND THEIR RELATION TO THE QUATERNARY SYSTEM $CaCO_3$–$MgCO_3$–$FeCO_3$–$MnCO_3$

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Subsolidus relations in the system $CaCO_3$–$MgCO_3$–$FeCO_3$ have been studied isothermally and essentially isobarically at 400°, 450°, and 500° C. and at CO_2 (+CO) pressures from 30,000 to 40,000 p.s.i. These studies indicated the presence of three one-phase areas (calcite s.s., magnesite-siderite s.s., and dolomite-ankerite s.s.), three two-phase areas (calcite s.s. + dolomite-ankerite s.s., siderite s.s. + dolomite-ankerite, and calcite s.s. + siderite s.s.), and a three-phase area (ankerite + calcite s.s. + siderite s.s.). Subsolidus relations along the join $CaMg(CO_3)_2$–$CaFe(CO_3)_2$ have been reported previously (Rosenberg, 1959).

In order to extend this study into the quaternary system $CaCO_3$–$MgCO_3$–$FeCO_3$–$MnCO_3$ several Mn-bearing systems were investigated under similar P-T conditions. A complete series of solid solutions was observed in the system $FeCO_3$–$MnCO_3$ at 450° C. The system $CaFe(CO_3)_2$–$CaMn(CO_3)_2$ is not binary, since an area of two ternary solid solutions occupies most of the join at 450° C. The single one-phase area near the composition $CaMn(CO_3)_2$ expands rapidly, however, with increasing temperature. The system $CaMg(CO_3)_2$–$CaFe(CO_3)_2$–$CaMn(CO_3)_2$ includes, at 450° C., a one-phase area, two two-phase areas, and a three-phase area which are extensions into the quaternary system of the phase areas encountered in the ternary system $CaCO_3$–$MgCO_3$–$FeCO_3$.

It is now possible to construct a preliminary, isothermal, quaternary diagram which serves to summarize present knowledge of this system.

ROTATED GARNETS AND THE DIASTROPHIC-METAMORPHIC SEQUENCE IN SOUTHEASTERN VERMONT

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Conventional structural data and topological implications of other geologic data suggest that two giant, recumbent, isoclinal, sigmoid folds in Paleozoic, metamorphosed, stratified rocks of southeastern Vermont predated the mantled gneiss domes with which they are structurally associated. The approximate axial parallelism of these folds, their respective structural positions above and below the main calcareous zone of the Waits River formation, and their mutually opposed shear senses suggest that these folds resulted from westward, intrastratal extrusion of the schists and impure marbles of the calcareous zone before doming.

Regional study of spirally arranged inclusions in garnets and directions of rotation determined therefrom confirms the early presence of a surface within and parallel to the calcareous strata across which the shear senses possessed mirror symmetry. After correction for effects resulting from rise of the gneiss domes, the rotational axes of the garnets parallel those of the giant recumbent folds; and the shear senses of the garnets agree with those of the folds. The garnets further indicate that the folds resulted from flexure.

Later upthrust of the gneiss domes manifests itself in conspicuous minor folds and reversal of the sense of rotation in the outermost portions of garnets beneath the above symmetry surface on the east limb of the Chester dome. There garnets show as much as 548° rotation for the early stage of deformation and 90° subsequent reversal resulting from doming.

Density data and deformational phenomena testify to the prominent roles of gravity and differences in plasticity in the diastrophic mechanism.

PRESSURE AND TEMPERATURE OF CRYSTALLIZATION FROM ELASTIC EFFECTS AROUND SOLID INCLUSIONS IN MINERALS?

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Earth processes commonly result in the transfer of a mineral grain from the pressure-temperature (P-T) condition of its origin to considerably different P-T conditions. If a mineral grain (h) includes a grain of another mineral (i), transfer to new P-T conditions commonly will cause anisotropic elastic strain effects around the inclusion because of different coefficients of thermal expansion (α) and compressibility (β) for the two minerals. To the extent that these elastic effects remain reversible over geologic time intervals, they represent stored information concerning the pressure and temperature of origin (P_0, T_0). The differential equation for the P-T curve representing no anisotropic stress around an inclusion of one isometric crystal inside of another isometric crystal is:

$$(dT/dP)_{P_i - P_h; T_i - T_h} = (\beta_h - \beta_i)/(\alpha_h - \alpha_i).$$

Experimental determination of two such curves for a given host containing two kinds of inclusions, known to have been included contemporaneously, would result in an intersection representing P_0 and T_0.

Among suggested techniques for determination of P-T curves is one using a window P-T bomb for observation of specimens between crossed polarizing filters to obtain the P-T co-ordinates for points of null piezobirefringence around inclusions.

The few noted natural examples of stress effects around inclusions in diamond and associated pyrope are consistent with extrapolations based on known values of α and β and inferred conditions within the earth. Examination of these minerals, having a probable origin in the mantle, should

allow determination of temperatures at pressures equivalent to depths of the order of 100 miles or more, using available equipment.

RADIOCHEMICAL DETERMINATION OF APPARENT AGE OF URANIUM MIGRATION IN SANDSTONE-TYPE ORE DEPOSITS

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The migration of uranium may be studied by the distribution of the radioactive daughter products, which serve as natural tracers in the migration of uranium. The distribution of the daughter products is determined by radiochemical analyses of samples from sandstone-type ore deposits. From the radiochemical analyses, the apparent minimum and maximum dates of uranium introduction or redistribution may be calculated from the Pa^{231}/Th^{230} ratio. The primary assumption required is that the protactinium and thorium do not migrate in measurable quantities from the place where they were produced by the radioactive decay of the parent uranium isotopes. This assumption in most cases is justified on the basis of the chemical properties of these two elements in natural geochemical environments. The practical limit of age determination is about 250,000 years, based on the 34,300 year half life of Pa^{231} and 80,000 year half life of Th^{230}. The difference in the half lives of these isotopes is reflected in their differential rates of growth and decay corresponding to migrations of the parent uranium during the time range considered. The growth and decay patterns, analyzed mathematically, are used to determine the apparent date of uranium migration.

The sandstone-type uranium deposits, for the purpose of calculation, are classified into those at or above the water table and those at considerable depth below the water table. Different methods are used to calculate the maximum and minimum dates of introduction and migration of uranium for the two classes of deposits.

FUSULINID DISTRIBUTION IN THE LEONARD FORMATION, PERMIAN, GLASS MOUNTAINS, TEXAS

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Twelve species of *Schwagerina* and *Parafusulina* are abundant in the Leonard formation. Distribution of these species is closely associated with particular rock types, and apparently depositional environment closely controlled species distribution.

In the lower 200 feet of the succession in the eastern and western Glass Mountains, *Schwagerina guembeli* and *S. crassitectoria* occur in silty calcilutite. In the lower 300 feet of the formation in the western Glass Mountains, *S. hawkinsi* is abundant only in conglomeratic biohermal limestone lenses, *S. hessensis* is most common in coarse calcarenite, and *Mondiexodina linearis* is common locally in fine- to medium-grained calcarenite.

In the lower 500 feet of the formation in the western Glass Mountains, a large species of *Parafusulina* commonly occurs in medium to coarse calcarenite. This lower sequence in both the eastern and western Glass Mountains has a primitive species of *Parafusulina* in clean calcilutite. Another primitive species of *Parafusulina* commonly occurs in limestone in a series of cyclothems beneath the upper Hess fossil bed in the eastern Glass Mountains. In the upper Hess fossil bed and in the first limestone member (King, 1931) of the Leonard formation in the western Glass Mountains, a third primitive species of *Parafusulina* is common in silty calcarenite. Higher in the formation in the eastern Glass Mountains, two small species of *Parafusulina* occur in oölitic limestone, and near the top of the formation in the western Glass Mountains a larger species of *Parafusulina* is common in silty and sandy calcarenite.

GEOMORPHOLOGY OF THE SOUTHERN PART OF CENTRAL IDAHO

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The present synthesis of geomorphic concepts concerns the part of central Idaho from near latitude 45° 30′ southward to the Snake River Plain. The writer's interest started in 1922.

A subdued erosion surface formed in early Tertiary time was so dissected as to set a regional topographic pattern that largely persists today. Shortly thereafter the Challis volcanics (largely Oligocene) blanketed much of the region, with accompanying intrusion, doming, and faulting. After this, erosion persisted long enough to produce a surface of low relief, controlled by local base levels rather than by sea level. Dissection of the composite post-Challis surface began before the Columbia River basalt covered the western part of the region in middle or late Miocene time. Isolated headwater basins, mostly near the eastern border of the area inundated by the basalt, retain detached bodies of lava and associated sedimentary rocks. The basins may have been modified and preserved by faulting. Post-Miocene dissection was followed by aggradation related to Pliocene and later regional tilting, faulting, and folding, accompanied by climatic changes. At least three stages of glaciation are recorded. Superposition on the various volcanic rocks and the successive deformational episodes, including recent recurrences, have resulted in drainage abnormalities, notably the erraitc composite course of the Salmon River through diverse valleys. At present, the high, relatively humid mountains are being eroded, and the semiarid valleys are being aggraded.

LOWER PALEOZOIC STRATIGRAPHIC PROBLEMS IN THE GREAT BASIN

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In the Great Basin, lower Paleozoic deposits may be grouped into three gross facies: (1) nearshore detrital, (2) carbonate, and (3) off-shore volcanic and detrital. Through much of early Paleozoic time the geographic positions occupied by these facies moved progressively eastward. However, preliminary detailed studies of such units as the Upper Cambrian Dunderberg shale facies by Palmer (1960), the Middle Ordovician quartzite facies by Webb (1958) and Hintze (1951; 1952), and the Silurian facies show that there may have been important variations or reversals of this trend. Great Basin Silurian and Devonian carbonate facies contrast sharply with Pacific Border province graywacke and volcanic facies which characterize these systems west of the Sierra Nevada, extending northward to southeast Alaska and beyond.

Precise biostratigraphy would permit comparisons between contrasting facies within shorter intervals than epochs. Such a comparison might be made to ascertain whether thicknesses of eugeosynclinal strata attain the great magnitude often attributed to them. Present evidence seems to show that Lower Ordovician eugeosynclinal rocks are thinner than contemporaneous carbonate deposits, and the opposite for Middle and Upper Ordovician strata.

A narrow area of reduced subsidence stretched from the Uinta uplift to the position of Eureka, Nevada, throughout the Ordovician (Tooele arch of Hintze, 1959). Its west end seems to have swung southeastward in Silurian and Devonian time. At times probably above water, this ridge may have deflected southerly currents carrying quartz sands from central Idaho westward into the eugeosynclinal realm.

AGE OF THE RIO GRANDE VALLEY IN SOUTHERN NEW MEXICO

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Gravels that contain jawbones of *Cuvieronius* and teeth of *Equus* border the Rio Grande Valley in southern New Mexico. According to Hibbard, this fauna association indicates a Kansan age. Three

well-developed paleosols stratigraphically separate the gravels from overlying sediments related to the Jornada-La Mesa surface. This surface cannot be older than early-mid Pleistocene. The Jornada part of the surface is an internally drained basin extending northward between the San Andres Mountains on the east and the Dona Ana-San Diego Mountains on the west. The La Mesa part of the surface was an internally drained basin extending southward into Chihuahua, Mexico, between the Franklin Mountains on the east and the Potrillo Mountains on the west.

The Rio Grande now is entrenched northwest-southeast through the La Mesa Basin, and is bordered by a stepped sequence of geomorphic surfaces cut below the Jornada-La Mesa surface. The Fort Selden surface, youngest of the stepped sequence, is less than 2620 ± 200 years old (U. S. Geol. Survey C^{14} date, W-819).

Distribution of gravel on the La Mesa surface west of the present Rio Grande Valley but derived from rocks in the mountains east of the present valley precludes existence of the valley in Jornada-La Mesa time. The Rio Grande cut through the rock gap (Paso del Norte) at El Paso, Texas, and extended northward in southern New Mexico in early-mid Pleistocene (Kansan-Yarmouth?).

STRATIGRAPHIC SETTING OF CHILEAN INTRUSIONS, THEIR LEAD-ALPHA AGE, AND THE RELATION OF OROGENY TO INTRUSIVE ACTIVITY

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Their stratigraphic setting demonstrates that three batholithic intrusions in northern and central Chile are of pre-Jurassic, Jurassic, and Cretaceous age. Radiometric age determinations, by the lead-alpha (Larsen) method, indicate ages of 265 ± 30, 120 ± 15 to 125 ± 15, and 95 ± 10 to 130 ± 15 m. y., respectively, for samples from the three batholiths. With only one exception, the radiometric ages are consistent with the stratigraphy. The exceptional determination of 130 ± 15 million years was for a sample of granite that intrudes rocks of Cretaceous age. The ages of three other samples of Cretaceous granitic rocks were determined to be within the range 95 ± 10 to 105 ± 10 m. y.

Angular unconformities whose ages are correlative with the intrusions suggest that the three batholiths can be related to Hercynian, Late Jurassic, and early Late Cretaceous orogenies, respectively.

THERMOLUMINESCENCE CORRELATION OF RHYOLITIC TUFFS

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Thermoluminescence glow areas of acidic volcanic rocks were studied. Lavas and tuffs from the same volcanic vent give very similar glow areas, characterized by the height of the glow-intensity maxima and minima and by their temperature dependence. Rocks of different sources have different glow characteristics.

For objective description two parameters were introduced, $T = T_{max} - T_{min}$ and $I = I_{max}/I_{min}$, with T (temperature) and I (intensity) of glow maxima and minima. In the T-I plot, tuffs and rhyolites of the same source fall in the same small area. Acidic rocks from different volcanic fields fall in different T-I areas, which never overlapped. Thus, correlation is accomplished.

One potassium-argon dated biotite-rhyodacite tuff from the Verde Valley of northern Arizona was correlated with various tuffs in that area and in the Hopi Buttes region. Supporting evidence for the validity of the correlation is by trace-element study, accessory minerals, and by vertebrate fossils (Lance).

The method is simple and cheap and permits rapid work. It can also be used for the detection of impurities in tuffs. Further investigations, also on basaltic lavas, are under way.

NEW EVIDENCE FOR PRIMARY DOLOMITE GRAINS FROM UPPER CRETACEOUS MARINE SANDSTONES OF THE WESTERN INTERIOR

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Many Upper Cretaceous marine sandstones from the Western Interior contain up to 25 per cent dolomite grains. These grains are individual rhombic crystals that have been abraded prior to deposition. They range up to medium sand size. For each thin section the size of the dolomite grains is related to that of the associated detrital sand grains. These relationships, plus the absence of any replacement fabrics, demonstrate that the dolomite grains are not of secondary replacement origin.

The grains were not derived from erosion of dolomite beds in the sediment source terrain because: (1) dolomite grains are restricted to the marine sandstones and are absent in the nonmarine sandstones, although detrital mineralogy shows that both facies were derived from the same source terrain; (2) within the marine sandstones, dolomite grains are least abundant in the shoreward facies. If the grains were detrital, they should be most abundant in this facies deposited nearest the source terrain; (3) identical dolomite grains occur in Upper Cretaceous sandstones from Alberta to New Mexico, despite the wide variety of source terrains shown by variations in detrital mineralogy.

Both replacement and detrital origins are thus eliminated, and it is concluded that these are primary dolomite grains which originated within the depositional basin. They were reworked at the depositional interface prior to burial with associated detrital sand grains.

Apparently these grains have not been reported previously because of failure to discriminate dolomite from calcite petrographically. Further investigation may provide new data on the origin of dolomite.

SOUTH CHILE EARTHQUAKE SWARM OF 1960

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Chile and parts of Argentina were shaken by earthquakes as great as M = 8½ on and subsequent to 21 May 1960. Activity began in Arauco Peninsula and spread southward to Taitao Peninsula.

Effects of the many earthquakes are difficult to differentiate. Intensities were highest along the coast between Lebu and Ancud and reached X to XI. Central Valley suffered lower intensities, VII to IX, except in localities with poor subsoil. A second narrow zone of intensity X lay east of the lake district.

Volcán Puyehue began erupting steam and ash between 1430 and 1500, local time, May 24. The other volcanoes remained quiescent.

Tsunamis were produced. In the largest (at coastal points in the epicentral region) the sea rose slightly during the main earthquake, withdrew 15–40(?) minutes, and advanced as a wave up to 10 m high. Several oscillations were reported.

As of June 20, three faults are reported to have moved, but none has been confirmed or studied in detail. Important faults in the region lie along the east edge of Arauco Peninsula to Chiloé Island, another along the west edge of the lakes, and another through Estrecho Reloncaví, across Lake Todos Los Santos, and beneath or near Volcán Puyehue.

Changes of elevation occurred along the coast. Lebu rose 1½ m. The coast from Puerto Saavedra to the south end of Chiloé sank 1–2 meters. In some places the change was temporary, recovery requiring several days; in other areas it seems permanent.

STRIKE-SLIP FAULTING IN NORTHERN CHILE

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Extensive dextral strike-slip faults parallel the north-trending coast line throughout most of northern Chile. A conjugate sinistral set strikes east to northeast and is particularly evident north of Iquique. Here the system rotates, so that the dextral faults trend northwest parallel to the Peruvian coast. Evidence of Recent activity decreases markedly inland.

The major north-trending Atacama fault zone probably is more than 1000 km long. Discontinuous breaks delineate its southern end for 300 km south from Copiapó, but northward the El Salado segment is clearly continuous for 180 km through El Salado to Taltal airport, where it is offset by a northwest-trending sinistral fault. The probable offset equivalent extends 450 km north from Paposa through Salar Remiendos and Salar Carmen to Salar Grande, where branches pass out to sea. Alluvial scarps testify to Recent activity along all segments of Atacama fault. Although the youngest displacements near Antofagasta have been predominantly vertical, an over-all history of dextral strike slip is suggested by (1) linearity over hundreds of kilometers, (2) rift topography, with no consistent differential elevation across the fault, (3) dextral stream offsets near Salar Grande, (4) mole-track scarps, and (5) widespread horizontal slickensides. Rakes of slickensides averaged 29° in 52 mines throughout northern Chile along this and subsidiary faults.

The largest demonstrable Recent displacements are on northeast-trending faults: sinistral stream offsets average 0.4 km along Camarones fault 7 km southeast of the mouth of Río Camarones, and a parallel fault 10 km east offsets Quebrada Chiza 1.5 km.

REPORT ON A VEIN MONTMORILLONITE FROM TOOELE COUNTY, UTAH

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A white montmorillonite, identical to hectorite in its waxy appearance, occurs as a fracture filling in siliceous extrusive rocks and is exposed in the Spider Uranium Mine, Honeycomb Cliffs, Tooele County, Utah.

X-ray diffraction, differential-thermal, cation-exchange, electron-microscope, infrared-absorption, and optical examination identify it as a pure montmorillonite.

Its formula is: $\left[Na_{0.10}K_{0.01} \left(\frac{Ca}{2} 0.06 \right) \frac{Mg}{2} 0.16 \right] (Li_{0.16}Mg_{.68}Al_{1.45})\ Si_4O_{10}(OH)_{1.09}F_{0.91}.$

This composition is similar to the aluminum bentonite from the North group of the Hector deposit but differs in its higher Li–F content and in containing mostly exchangeable magnesium rather than sodium.

Its thermal and hydrothermal decomposition characteristics are intermediate between hectorite (Li–F saponite) and the Li–F aluminum montmorillonite from the Hector deposit.

Apparently Li–Mg–F solutions produced this montmorillonite. This raises the question of whether the magnesium in hectorite was extracted from the alkaline lake waters, as has been proposed.

APPLICATION OF REACTION Eh-pH DIAGRAMS TO THE PROBLEMS OF SUPERGENE OXIDATION AND ENRICHMENT OF SULFIDE ORE BODIES

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Reaction Eh-pH diagrams, based on the potentials of observed oxidation and reduction reactions, show the limits of metastability of minerals in aqueous environments; they supplement equilibrium

(stability) diagrams in kinetic aspects of geochemical processes. Comparison of reaction diagrams for several sulfide minerals indicates two separate electrochemical series for sulfides: oxidation and reduction.

In the oxidation series, the order and magnitude of reaction potentials depend directly on the activities of metal ions and indirectly on the activities of hydroxyl, carbonate, or other ions that form solids or complexes with the metal ions. For unit activities of metal ions, argentite .82 (volts) is followed by pyrite .76, covellite .59, chalcocite .53, galena .35, and sphalerite .27; for 10^{-6} activities pyrite .58 is followed by argentite .47, covellite .41, chalcocite .35, galena .18, and sphalerite .09. These sequences would correspond to increasing ease of oxidation in the zone of active oxidation and leaching where acidity is high.

Precipitation of solids by hydroxyl ion and/or carbonate ion causes lowering of metal-ion activities as functions of pH in neutral to basic solution. At pH 7 and under P_{CO_2} equal to that of the atmosphere, the sequence is: argentite .72, covellite .41, chalcocite .35, pyrite .33, sphalerite .20, and galena .20. This order would apply to the zone of secondary enrichment where neutralization by rock-forming minerals is effective. Excepting pyrite, an earlier mineral in the sequence will replace a later one.

INTEGRATION OF LAND-MAMMAL GEOCHRONOLOGY AND POTASSIUM-ARGON GEOCHRONOMETRY

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Composite aggregates of fossils of land mammals from scattered localities in the United States were the basis for the subdivisions of Cenozoic geochronologic time ("Mammal ages") that are now applied by vertebrate paleontologists to nonmarine strata on this continent. Many of the matrices of the mammalian fossils are volcanic in origin or have a direct stratigraphic association with potassium-rich tuffs and flows. These associations provide an excellent opportunity for a reciprocal evaluation of the land-mammal geochronology and the potassium-argon geochronometry.

Tested samples from Texas, Nebraska, Wyoming, Nevada, Oregon, and California indicate that the Chadronian mammal age (early Oligocene) includes a date of 33 million years before present; the late Arikareean (early Miocene) includes 22 m.y.b.p.; Hemingfordian (early mid-Miocene) includes 17 m.y.b.p.; Barstovian, including type Barstovian (middle to late Miocene), includes 15 m.y.b.p.; Clarendonian (late Miocene-early Pliocene transition in its broadest connotation) ranges from about 12 to 9 m.y.b.p.; Blancan (late Pliocene and early Pleistocene) probably extends back to 2 m.y.b.p. These conclusions must be taken as current approximations, which will be refined by the testing program designed to be under way during the next few years.

PHASE TRANSFORMATION IN THE SYSTEM AgI

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Records of the X-ray-diffraction intensities of key spacings vs. temperature show that the β-α AgI transformation (B4-B23) is first order with a marked hysteresis effect. The following observations appear anomalous. The transformation exhibits the lambda specific heat curve characteristic of second-order transformation. The transformation temperature ranges from 148° C. to 155° C. On cooling back through the inversion, a mixture of γ-AgI (B3) with β results. The proportion of β:γ is approximately 60 per cent and variable. Heat treatment of samples of high β:γ ratio in the range 120°–135° C. may decrease the ratio. Heat treatment of samples of low β:γ ratio in the same range invariably increases the ratio.

These anomalies are intelligible if the γ-β transformation is second order with a critical temperature masked by the intervening transformation to the α form above 150° C. Unmixed β or γ AgI are metastable below this temperature. The equilibrium proportion β:γ is a function of temperaure, but transformation to an equilibrium ratio is sluggish except on cooling through the 150° C. inversion.

ORIGIN OF THE BOSPORUS

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Since early catastrophic theories by Strabo and Pliny the Bosporus has been variously regarded as (1) a graben, (2) a drowned valley of an "Aegean River" draining the Black Sea via the Dardanelles into the Mediterranean, or a "Pontic River" flowing in the opposite direction, (3) a local drainage line with its middle course in the Golden Horn, emptying northward into the Black Sea and modified by submarine erosion.

Pertinent data include (1) post-Miocene tectonic history of the area, (2) local drainage pattern and barbed tributaries, (3) gradients of terraces and the Upper Tertiary "Thracian peneplain," (4) submarine steps at the mouths of tributaries, except the Golden Horn, (5) Bosporus bottom topography, sediments, and bedrock depth, (6) hydraulics of Bosporus currents, (7) Pleistocene changes in sea level and Black Sea salinity revealed by marine terraces and sediments, (8) Black Sea bottom topography.

The evidence shows that the ancestral Bosporus valley was part of a southward drainage pattern, following a fault zone. During the Pleistocene it was alternately a marine strait and a marine spillway or subaerial valley. Sedimentation alternated with erosion. Depth changes can be charted through known influxes of saline Mediterranean waters into the Black Sea. In latest Pleistocene the Black Sea level dropped greatly, owing to tectonism. A northward stream cut a canyon into the exposed shelf and displaced its head southward to the mouth of the Golden Horn, reversing the ancestral drainage. This valley was drowned and modified by submarine currents in Recent time.

ANTARCTIC COAL GEOLOGY

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Antarctic coal deposits are now reported from nine widely separated areas. All but one are within the Beacon sandstone located along the general line of escarpment on the "Horst," between Eastern Antarctica and Western Antarctica. This distribution seems to bear out L. M. Gould's prediction that one of the world's most extensive coal fields is located adjacent to the South Pole.

Coal analytic information is available from four of the areas. The lowest-rank, and possibly youngest, coal is reported by P. W. Crohn from the isolated Amery occurrence near the Indian Ocean edge of Antarctica. Old analyses of coal along the escarpment from the Beardmore glacier area, given by T. W. E. David and R. E. Priestley, suggest that coal there is high rank. Recent sampling of coal from Mount Gran in the Granite Harbour area by John Mulligan of the U. S. Bureau of Mines bears out Frank Debenham's assertion that this coal also is variably high rank, much altered by igneous intrusions. New analyses from Mount Glossopteris in the Central Horlick Mountains suggest that the coal there has not been affected by igneous activity and is semianthracitic (moisture- and mineral-free fixed carbon, about 89 per cent). Apparently it does not differ much from the rank of coal at the western edge of the Middle Anthracite field in Pennsylvania.

Comparison with Permian coal in Eastern Australia and South Africa seems most pertinent. If present rank is proportional to the maximum previous overburden, a somewhat greater thickness of cover seems indicated for the Horlick deposits, which are located near the axis of A. DuToit's postulated Samfrau geosyncline.

GEOCHEMICAL STUDIES ON THE McMURRAY SAND OIL AND SELECTED ALBERTA BASIN CRUDE OILS

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Chemical characterizations of the oils impregnating the McMurray sands from Bitumount to Grand Rapids and of selected Cretaceous and Devonian crude oils produced in the Alberta Basin have been determined. These crude oils were first treated for precipitation of the asphaltenes, followed by chromatography of the asphaltene-free oil in activated alumina. Chromatographic fractions were obtained by elution with pentane, benzene, and benzene-methanol (4:1). The portion of the pentane eluates with molecular weight above 200 were then characterized by ring-analysis methods (van Ness and van Westen) and by mass spectrometry. The ring-analysis data for the McMurray oil and for a Lower Cretaceous crude oil produced at Lloydminster gave similar results; parallel changes in the hydrocarbon structures with increasing molecular weight were also noted in these two oils. Mass-spectrometric group analysis of the McMurray and Lloydminster pentane eluates showed the absence of free alkanes; about 40 per cent of the hydrocarbon components were made up of noncondensed cycloalkanes and another 40 per cent of condensed cycloalkanes. Equivalent fractions of Devonian crude oils gave substantial differences in the ring analyses from those obtained in the Lower Cretaceous oils; the mass-spectrometric results of the Devonian pentane fraction showed the presence of 28 per cent free alkanes, 39 per cent noncondensed cycloalkanes, and 21 per cent condensed cycloalkanes.

Laboratory reactions of elemental sulfur with the Lloydminster crude oil resulted in the formation of an oil superficially and chemically similar in character to that impregnating the McMurray sands. A selected Devonian oil on similar treatment failed to produce this similarity. Further studies employing the radioisotope S^{35} indicated the specific fractions of the crude oil responsible for these differences in chemical behavior.

SYNTHETIC HYDROUS AND ARGON-BEARING CORDIERITES

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Synthetic hydrous Mg-cordierites show a positive linear correlation between water content and mean index of refraction. Up to 2.75 weight per cent water may be contained in the cordierite structure; the value depends on the water pressure and temperature of the experiment. On the basis of index-of-refraction measurements the water content of hydrous Mg-cordierite has been delineated within its stability field up to 10,000 bars water pressure. The water content gradually increases with increasing water pressure and decreasing temperature. Heating of hydrous cordierites at atmospheric pressure causes a gradual water loss between 200° and 700° C. Conversely, anhydrous Mg-cordierites can be hydrated under elevated water pressures. Infrared studies of synthetic hydrous Mg-cordierites indicate the presence of two types of water: "free water" (molecular H_2O) and "bound water" (OH^- groups).

At 10,000 bars argon pressure, 900° C., anhydrous Mg-cordierites incorporate as much as 2 weight per cent argon, which results in a similar increase of the mean refractive index. By heating at atmospheric pressure argon is expelled more slowly than water from the cordierite structure.

The argon as well as most of the water is probably located in open channels parallel to *c* of the cordierite structure. The high compressibility of argon relative to cordierite under pressure may account for its passage through structural holes in cordierite, which at atmospheric pressure are smaller than the argon atoms.

These results bear on the problem of the retention of argon produced by radioactive decay of associated potassium-bearing minerals.

DURABILITY STUDIES OF CHERTS AND SHALES IN GRAVELS

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Certain cherts and shales have long been recognized as harmful when included in aggregates used in portland-cement concrete, and many State highway departments have specifications limiting percentages of these materials in concrete aggregates. Few of these specifications, however, distinguish between types of chert and shale.

This study attempts to correlate basic physical properties of cherts and shales in gravels with the freeze-thaw durabilities of these materials when used in portland-cement concrete. Samples of cherts and shales from nine glacial gravel deposits in Indiana were studied petrographically, and their pore characteristics were investigated by specific gravity and absorption techniques. Blends of 2, 4, 6, and 10 per cent of chert or shale from each source were made with a standard durable crushed-limestone coarse aggregate, and these blends were used in air-entrained concrete beams 3 by 4 by 16 inches. The beams were subjected to up to 300 cycles of freezing and thawing in an automatic freeze-thaw machine. The rates of deep-seated deterioration of the beams as measured by loss of strength were obtained by means of nondestructive sonic testing, and severity of surface "popout" deterioration was noted.

For the concretes containing chert, significant deep-seated deterioration and appreciable surface deterioration occurred only in those beams containing 6–10 per cent of the most porous fractions of the chert samples. None of the shales caused deep-seated failure of the concrete, but the most porous shales caused severe "popout" damage.

SEDIMENTATION AND REGIONAL METAMORPHISM PRIOR TO INTRUSION OF THE SOUTHERN CALIFORNIA BATHOLITH

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In the vicinity of Hemet, California, a 13,000-foot-thick sequence of quartzite, schist, and minor amphibolite, called "Paleozoic schist" by Larsen (1948), lies conformably on the Bedford Canyon formation (Triassic or younger). This section of metasedimentary rock was derived from a series of shales, shale-clast conglomerates, poorly sorted feldspathic, calcareous, and arkosic sandstones, and rare basalt flows or tuffs. Relict sedimentary structures and textures are well preserved in part.

These sedimentary rocks were intruded by a series of basic and ultrabasic magmas and were tightly folded prior to late Cretaceous. In the late stages of folding they underwent regional metamorphism to the hornblende-hornfels facies, at 200°–600° C. and 3–5 kb. Three isograds are mapped, trending north-south athwart the northwest-southeast structural trend of the folded rocks. They are defined by the successive eastward appearance in pelitic rocks of andalusite, sillimanite, and almandine (with increasing metamorphic rank). Parallel sequences are shown in other lithologies: in amphibolite, from hornblende-andesine to hornblende-diopside-andesine to hornblende-garnet-diopside-labradorite; in calc-silicate quartzite from quartz-epidote-calcite-hornblende-oligoclase to quartz-hornblende-diopside-grossularite to quartz-diopside-wollastonite-grossularite. The highest-rank (eastern-most) pelitic rock is migmatite gneiss.

The metamorphic zones are of regional extent and unrelated to adjacent intrusive igneous rocks of the Southern California batholith. They were presumably formed prior to the intrusion of the batholith.

EXTRACTION, SEPARATION, AND CHARACTERIZATION OF THE HIGH-MOLECULAR-WEIGHT ORGANIC MATERIALS IN SOIL

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A Brookston silty clay loam was used as a model system to develop methods for the extraction, separation, and characterization of high-molecular-weight soil organic matter.

Water extraction removed approximately 8 per cent of the total soil organic matter. Most of the water extract consisted of low-molecular-weight compounds. The high-molecular-weight material was composed mainly of polysaccharides which were separated into four main components on a continuous-flow paper electrophoresis apparatus. The charge on the polysaccharides was due to uronic-acid groups.

Neutral pyrophosphate solution extracted approximately 25 per cent of the total soil organic matter. Inorganic and low-molecular-weight organic material were removed either by dialysis or pressure filtration. A clay contaminant could not be removed by centrifugation but could be removed by treatment with a solution 0.3 M in HCl and 0.3 M in HF.

Infrared spectra of the acid-precipitable organic matter from the pyrophosphate extract showed that the charge on these polyelectrolytes must be due mainly, if not completely, to carboxylic acids. When applied to the continuous-flow paper electrophoresis apparatus, this brown material consisted of one main component. The use of infrared spectroscopy to monitor the electrophoresis runs was found to have certain advantages over purely chemical tests.

LAZAREVIĆITE, A NEW CUBIC COPPER-ARSENIC SULFIDE FROM BOR, JUGOSLAVIA

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Lazarevićite is a new cubic copper-arsenic sulfide, ideally Cu_3AsS_4, from the Tilva Mika copper deposit at Bor, eastern Serbia. It occurs as microscopic grains in copper ore associated with enargite, luzonite, covellite, and pyrite. The mineral is named for M. Lazarević, pioneer investigator of the geology and ore deposits of Bor, 1908–1913.

An electron-microprobe analysis showed that lazarevićite contains 52.5 per cent copper, 12.5 per cent arsenic, and 1.9 per cent iron. These and spectrochemical data indicate that the stoichiometric formula of lazarevićite is $[(Cu_{.81}As_{.18}Fe_{.02}V_{tr})_1S_1]$.

X-ray-powder diffraction data show that lazarevićite has the sphalerite-type structure with $a_0 = 5.28 \pm 0.01$. The space group is $P\bar{4}3m$ with atomic co-ordinates: 3 Cu in (c) $0\frac{1}{2}\frac{1}{2}$; 1 As, Fe, or excess Cu in (a) 000; 4 S in (e) $\frac{1}{4}\frac{1}{4}\frac{1}{4}$. The structural formula is $[Cu_3(As_{.81}Cu_{.22}Fe_{.18}V_{tr})S_4]$, $Z = 1$, and the calculated density is 4.39 gm/cc. Lazarevićite has the structure of arsenosulvanite $[Cu_3(As, V)S_4]$, and its composition approaches the hitherto unknown arsenic-rich end of the sulvanite-arsenosulvanite atomic substitution series.

In polished section lazarevićite resembles enargite but is characterized by its isotropy in polarized light, distinctive yellowish-brown tint, and selective etch reactions with HNO_3 and KCN.

The copper deposits at Bor occur in hydrothermally altered intrusive andesite. The sequence of hypogene sulfide deposition in the Tilva Mika deposit is (1) pyrite, (2) enargite and minor luzonite, (3) chalcopyrite, bornite, pyrite, and gold, (4) digenite, and (5) covellite and minor enargite, pyrite, and galena. Lazarevićite was introduced in the waning stages of (2) and (5) partly by replacement of enargite.

COMPOSITION OF THE ATHABASCA PETROLEUM IN THE VICINITIES OF McMURRAY, BITUMOUNT, AND FORT MACKAY IN ALBERTA, CANADA

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The semisolid organic matter impregnating the sandstone and shale beds of the McMurray formation, Alberta, Canada, is a petroleum. This petroleum is characterized by relatively high asphaltene and sulfur contents. Spectroscopic methods of analysis led to the identification (or tentative identification) of the following compound types in a sample from the vicinity of McMurray: (1) hydrocarbons: paraffins, naphthenes, alkyl benzenes, cyclo-alkyl benzenes, naphthalenes, and phenanthrenes; (2) nonhydrocarbons: pyridines, pyrroles, carbazoles, benzothiophenes, and thiophenophenanthrenes.

An attempt was made to gather information regarding the development of the deposit. The preferential accumulation of some of the petroleum constituents has been investigated along a suggested migration path. Core samples from three bore holes, lying along a southwest-northeast cross section, in the Bitumount and Fort MacKay area, have been analyzed by a multistage elution method. Some variations were observed along both horizontal and vertical directions in the recoverable saturated hydrocarbon and asphaltene contents and in the "Kleinschmidt" dark-oil content.

Some of the reasons which may account for the semisolid nature of the Athabasca petroleum have also been studied. Air was passed through liquid petroleum samples from Oklahoma and Alberta for prolonged periods of time. A surface active agent or colloidal sulfur has been added to some of the samples. The weathering tests increased the viscosities and the asphaltene contents of the samples

HYDROCHEMICAL FACIES AND GROUND-WATER FLOW PATTERNS IN THE ENGLISHTOWN SAND IN THE COASTAL PLAIN OF NEW JERSEY

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The concept of hydrochemical facies has been used to demonstrate regional relations between chemical content of ground water, lithology, topography, and flow patterns in the Atlantic Coastal Plain. This paper is a progress report examining the detailed hydrochemical facies in a particular formation within a selected part of the hydrologic system. The Englishtown sand in the coastal plain of New Jersey was selected as a field model because of its uniform lithology; because data are available concerning clay minerals, heavy minerals, fossils, the quality of the ground water, and water levels; and because wells for sampling the water are strategically located. The geographic distribution of concentrations of individual ions and ionic ratios are compared with topographic, isopachous, and structure-contour maps, and with a generalized ground-water flow pattern. Various hydrochemical facies can be related to geology and hydrology.

Water-level observations indicate that most recharge for the Englishtown sand occurs under a topographically high landmass 5–10 miles downdip from the outcrop. Although parts of the outcrops of other formations in the Atlantic Coastal Plain function as discharge areas, the entire outcrop of the Englishtown sand is considered a discharge area. A calcium bicarbonate facies in the recharge area results from solution of calcareous material from overlying formations. Concentrations of dissolved solids decrease laterally away from this recharge area and increase at depth. Ion exchange with montmorillonite results in a sodium bicarbonate facies at depth. Nonmarine deposits of the Englishtown are characterized by kaolinite, chlorite, and illite, contrasting with montmorillonite in the downdip marine beds.

ERUPTION OF WATER, SAND, AND CLAY RESULTING FROM THE EARTHQUAKE OF MAY 21, 1960, NEAR CONCEPCIÓN, CHILE

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A side effect of the earthquake of May 21, 1960, near Concepción, Chile, was the eruption of water, sand, and clay from fissures and circular or elliptical vents in a cultivated field and in tidal mud flats near the mouth of the Bío Bío river. According to eye-witness accounts, muddy water continued to erupt for about 6 hours after the earthquake.

Small ridges of sand along the fissures and cones of sand at the other vents were formed. Craterlike depressions in the center caused the cones to resemble volcanoes. Some of the miniature "volcanoes" were double, others were breached on one side, still others had minute "satellite" cones. "Bombs" of clay and peat were ejected from the "craters" and from fissures. Small cavities extended under the clayey topsoil.

The accumulations of erupted sand ranged in width from 5 to 70 cm, and they attained a maximum height of about 10 cm above the adjacent soil surface. Some of the fissures attained lengths of several tens of meters. Clay "bombs" as much as 20 cm across and 7–8 cm thick were found as far away as 1.2 m from the nearest fissure or "crater".

The eruptive phenomena were restricted to sunken areas, as much as several hectares in extent, which had been displaced vertically at least 20–30 cm. The ejection of water and clastic material was apparently caused by settling and compaction of water-soaked sediments and rupture or perforation of the overlying topsoil.

QUANTITATIVE FOSSIL CORRELATIONS

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Occurrences of fossils in two sections can be viewed as statistical samples of a normal, bivariate population. As such, they can be graphed and expressed as regressions (normally rectilinear) by means of the "least squares fit." This renders the Standard Error of Estimate a direct measure of the reliability of fossil correlations. By the use of regressions all fossil occurrences can be projected into a single, mathematically created Composite Standard which serves as the cumulative basis for further correlations.

Analysis of the Cambrian fauna of the Riley formation of Texas, described by Palmer (1954), yields correlations whose Standard Errors of Estimate range from 0 to 5.3 feet, depending on the amount of control in each section. On this basis, the interval now divided into the unequally thick *Bolaspidella*, *Cedarina-Cedaria*, *Coosella*, *Maryvillia*, *Aphelaspis*, and post-*Aphelaspis* zones can be divided into more than 38 equal-sized time zones, correlatable at the 95 per cent confidence level. The more precise control obtainable by regression confirms the correctness of Palmer's larger subdivisions.

A Composite Standard of the species described by Palmer has been completed. At a level of accuracy 95 per cent or better, it will permit correlations between time intervals in other sections where the same fossils are present and 11-foot intervals of the Riley section.

OUTER TERMINATIONS OF WEST COAST SUBMARINE CANYONS

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Hitherto, little has been known about the outer ends of submarine canyons. Recent extensive soundings with Precision Depth Recorders of the canyons in the San Diego area, and around the

tip of Lower California, have given detailed information on their seaward termination. There are definite fans off all these canyons, but off La Jolla and Coronado canyons the fans are truncated by channels in continuity with the inner rock-walled canyons, whereas off Baja California the rock canyons end abruptly near 1300 fathoms, and no definite channels traverse the extensive fans. The channel off La Jolla Canyon terminates near the base of the fan in San Diego Trough, whereas the channel off Coronado Canyon crosses the lower end of San Diego Trough as a valley 100 fathoms deep with a basin depression and finally ends on the slope leading into San Clemente Trough farther west. Both of these channels have sandy sediment along the greater part of their length and locally contain fine gravel.

The canyons at the lower end of Lower California have granite walls extending out to at least 1000 fathoms, and, as far as is known, the canyon floors are sandy throughout their length, with coarse sand near the outer end. The entire continental slope in the vicinity of these canyons is as much dissected as the mountain ranges along the adjacent coast.

MESOZOIC STRATIGRAPHY OF THE GREAT BASIN

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Stratified rocks of Mesozoic age in the Great Basin can be grouped into four assemblages: (1) the nearly complete succession of marine Triassic and Lower Jurassic sedimentary and volcanic rocks in northwestern Nevada, extending into northern California; (2) the marine Lower Triassic sedimentary rocks of northeastern Nevada and northwestern Utah, genetically related to similar rocks in the Middle Rocky Mountains; (3) the mainly continental Triassic, Jurassic, and Cretaceous rocks in southernmost Nevada and southwestern Utah, which have affinities with the Colorado Plateau section; and (4) the isolated exposures of nonmarine mainly conglomeratic Lower Cretaceous rocks in central and northwestern Nevada. Mesozoic rocks are either unknown or of very limited extent in a large part of southern and east-central Nevada and west-central Utah.

During middle and late Early Triassic time an epicontinental sea extended from southeastern Idaho through the eastern Great Basin into southern California. In northwestern Nevada this time is represented by stratigraphic hiatus, after which marine deposits of Middle Triassic to Early Jurassic age accumulated mainly on the eastern shelf of a geosyncline. No major topographic barrier is envisaged between this marine basin and the area of continental Upper Triassic and Lower Jurassic deposition in the southern and eastern Great Basin. During later Jurassic and Cretaceous time recurrent uplift and deformation occurred; nonmarine orogenic sediments accumulated in local basins within the Great Basin, and large amounts of clastic debris were shed eastward into the Cretaceous seaway of the western interior.

AGE DETERMINATIONS ON PRECAMBRIAN DIABASE DIFFERENTIATES IN THE SIERRA ANCHA, GILA COUNTY, ARIZONA

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Granitic differentiates of diabase sills intrusive into formations of the Apache group of the Sierra Ancha region contain a number of uranium- and thorium-bearing minerals suitable for age determinations. Preliminary isotopic analyses on some of these minerals give a minimum age of 1075 ± 50 million years and a probable age of 1200 million years or greater. This places a younger age limit on the Apache group and also on rocks assigned to the Troy quartzite in this region. Since the diabase can only be restricted to pre-Devonian in the Sierra Ancha region, a significant gap in the local geologic record is confirmed. The apparent age of the diabase is compatible with ages reported for uranium mineralization in the Dripping Spring quartzite of the Apache group. The age relations

tend to support suggestions of a genetic affinity between the diabase and the uranium mineralization. Evidence must be considered for an important younger event (late Mesozoic?) affecting minerals of both the diabase and the uranium deposits.

HYPOGENE MINERAL ZONING, CENTRAL CITY DISTRICT, COLORADO

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The gold- and silver-rich base-metal sulfide ore deposits of the Central City district, Colorado, are arranged in well-defined concentric zones manifested by systematic changes in mineralogy, metal content, metal ratios, and mineral textures. The zones extend southwestward into four adjacent mining districts.

The principal mineralogic zones in the Central City district consist of a central core of pyrite-quartz veins and an outer zone, not present to the south, of veins containing dominant galena and sphalerite in a quartz or less commonly a carbonate, barite, or fluorite gangue. Transitional veins in an intermediate area are pyritic veins that contain copper minerals, galena, and sphalerite. Chalcopyrite and tennantite are the dominant copper minerals; locally this assemblage is replaced by enargite and tennantite.

Gold and copper decrease, and concomitantly silver, zinc, and lead increase outward; also, silver-gold, lead-copper, and zinc-copper ratios increase outward. The quartz gangue becomes noticeably finer-grained outward.

The succession of zones accords in general with the sequence of deposition of the vein minerals. Sulfide mineralization began with the deposition of quartz and pyrite (pyrite stage mineralization) and concluded with the deposition of gangue and base-metal sulfides (base-metal stage mineralization), which generally crystallized in the order pyrite, sphalerite, chalcopyrite, enargite (local), tennantite, and galena. The minerals of the base-metal stage were deposited in the outer part of the area of the original pyrite-quartz veins and in the surrounding area.

GEOMICROBIOLOGICAL EFFECT ON HYDROGEN-ISOTOPE EQUILIBRIA IN THE MARINE ENVIRONMENT

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The three isotopes of hydrogen, protium, deuterium, and tritium, are selectively fractionated by microorganisms during metabolic processes involving hydrogen compounds.

Samples of gas from marine sediments and from bacterial fermentation analyzed by mass spectrometer reveal a protium concentration greater than that expected from nonbiological processes. In the marine environment various microorganisms, particularly those containing hydrogenlyase and hydrogenase enzymes, apparently play an important role in hydrogen-isotope equilibria.

Mechanisms by which microorganisms fractionate the hydrogen isotopes involve enzyme specificity, bond-cleavage rates, cell-wall diffusion, and the formation of large insoluble molecules—*e.g.*, protein-bound polysaccharides. The latter process resembles a sequestration effect in that the heavy-isotope atoms are prevented from equilibrating with the medium as long as the cell wall is intact.

After cell death and disintegration, predicted chemical equilibria are re-established. Laboratory studies involving microbial activity on tritium compounds reveal a multistaged process by which protium and tritium are fractionated.

The writer concludes that marine microorganisms are important geochemical agents in dynamic processes involving hydrogen and other isotopes in the sea.

STRATIGRAPHY AND STRUCTURE IN THE SOUTHERN PART OF THE GREEN MOUNTAIN ANTICLINORIUM

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The Wilmington-Woodford area of southernmost Vermont comprises 385 square miles of metamorphosed Precambrian and Lower Paleozoic rocks. This area lies across the anticlinorium where the central core of Precambrian rocks plunges southward under Lower Paleozoic strata.

The older rocks of the anticlinorium are earlier Precambrian and consist dominantly of microcline augen gneiss, plagioclase gneiss, quartzite, conglomerate, and lime-silicate granulite. These strike east-northeasterly and are separated from younger Precambrian strata by a sharp angular unconformity. The latter comprise conglomerate and quartzite, albite schist, marble, and lime-silicate granulite overlain by distinctive, highly aluminous schists.

The central core of the anticlinorium is bounded on the east by northeasterly striking Lower Paleozoic strata whose lithology is similar but not identical to that of the younger Precambrian sequence. In addition, the Paleozoic rocks overlie the latter with angular unconformity which, however, is not everywhere well developed.

The existence of the Hoosac thrust of Prindle and Knopf (1932) is verified in the southern part of the area and east of the axis of the anticlinorium. Here Precambrian rocks are thrust westward over Lower Cambrian Cheshire quartzite. Eleven miles east of the axis of the anticlinorium is a nappe, in the core of which is microcline augen gneiss correlated with similar gneiss of the Green Mountain core.

The Mendon and Cheshire formations of the western flank of the anticlinorium grade into the Tyson and Hoosac formations of the eastern sequence.

ASSEMBLAGE ENARGITE-FAMATINITE, A POSSIBLE GEOLOGIC THERMOMETER

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As part of a detailed study of the system Cu–As–Sb–S, phase relations along the join Cu_3AsS_4–Cu_3SbS_4 have been investigated by means of experiments in sealed, silica-glass tubes.

The only phases observed correspond to the mineral enargite (Cu_3AsS_4) and the isomorphous series luzonite (Cu_3AsS_4)-famatinite (Cu_3SbS_4).

Enargite (wurtzite-type structure) is the high-temperature polymorph of luzonite (sphalerite-type structure).

The stability field of enargite is separated from the famatinite field by a solvus in which the assemblage enargite plus famatinite is stable. Famatinite solid solutions are stable up to the melting curve, above which the system is no longer binary.

The two-phase assemblage enargite plus famatinite, frequently reported in nature, may be useful as a geologic thermometer. For this purpose, the compositions of the coexisting enargite and famatinite must be known.

The unit-cell edges of enargite (orthorhombic) and of the series luzonite-famatinite (tetragonal) change linearly with composition and provide a sensitive means of determining compositions. Unit-cell edge measurements reported for natural minerals are in good agreement with the unit-cell edges of the synthetic phases.

FORMATION OF MODERN DOLOMITIC SEDIMENTS IN SOUTH AUSTRALIAN LAGOONS

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Magnesian calcite and calcian dolomite precipitate in intermittent saline lagoons and an elongate, shallow marine bay (locally called the Coorong) in the southeast of South Australia.

The ratio of dissolved salts in the saline waters is constant and almost identical to that of sea water, but the salinity varies widely during carbonate precipitation. The waters support abundant plant and animal life during spring and early summer months.

A number of samples were collected with the precipitated solids still in suspension. The precipitates are mixtures of magnesian calcite, ranging in composition from $(Ca_{0.84}Mg_{0.16})\ CO_3$ to $(Ca_{0.77}Mg_{0.23})\ CO_3$, and calcian dolomite of essentially constant composition $Ca_{0.56}Mg_{0.44}\ CO_3$. Small amounts of celestite ($SrSO_4$) were observed in all precipitates, reaching a maximum of about 3 per cent. The dolomite content ranged geographically from 0 to 50 per cent but remained constant for a given locality during the 2-year period of observation.

X-ray-powder-diffraction patterns of the dolomites show weak-order reflections in many samples. The dolomites may reasonably be classified as protodolomites.

Auger holes into the bottoms of the lagoons indicate only a few feet of carbonates, below which coarse sands were encountered. The writer believes that the carbonate sediments are the final stage in the progressive infilling of the lagoons and retreat of the Coorong, and as such carbonate precipitation may not have occurred in any given locality for a long period.

INTERREGIONAL TIME-STRATIGRAPHIC CORRELATION

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Geologic time is divisible according to two kinds of time scales: an interval (chronologic) scale of equal units (years and multiples of years); and an ordinal scale in which units have a defined rank but lack equality or regularity. Reference of strata to a chronologic scale requires direct measurement of time, and no methods of sufficient accuracy for stratigraphic purposes have as yet been developed. Assignment of strata to positions on the ordinal scale (*i.e.*, to system, series, or stage) and the time correlation, or determination of relative ordinal age, of geographically separated strata are inferential procedures.

Paleontology is only one field of data from which time-stratigraphic inferences may be drawn. Nevertheless, virtually all regional and interregional published correlations are expressions of biostratigraphic inference alone. Where adequate index taxons of defined range are lacking (as in the Middle Paleozoic of large areas) conflicts and inconsistencies are recorded. Use of horizons of apparent synchroneity, of time-parallel stratal units, and of position with reference to depositional cycles and regional unconformities as valid criteria of ordinal age facilitates re-evaluation of a number of paradoxical biostratigraphic correlations. Such re-evaluations commonly result in greater harmony among several contributing lines of evidence and permit recognition of a more rational and consistent succession of paleogeographic patterns.

MESOZOIC THRUST FAULTS IN THE NORTHERN WALLOWA MOUNTAINS, OREGON

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Major thrust faults in northeastern Oregon are reported for the first time. Sheets of folded Triassic strata were thrust over Permian volcanic rocks during a middle Mesozoic orogeny and subsequently were invaded and further deformed by the Wallowa batholith.

During the main orogeny, Triassic rocks were sheared from underlying Permian rocks along an extensive decollement thrust plane and moved north-northwestward. Some Permian rocks were involved in the upper plate, but most remained in the lower plate which structurally forms the basement mass. The decollement thrust overrode and truncated an older, steep, sheared and imbricated east-northeasterly fault zone.

At least five thrust sheets developed above the basal decollement and piled up above each other as they moved north-northwestward. These faults include both thrusts of older over younger rocks and thrusts of younger over older rocks. Highly compressed and recumbent folds are an integral part of the piled thrust sheets; some of the sheets may have originated by the shearing of folds along their overturned limbs.

A north-northwest-trending syncline was superimposed on the thrust structure in the northwestern part of the area, perhaps as a regional buckling of the thrust belt. Several composite stocks were emplaced along this syncline. Subsequent forceful emplacement of the Wallowa batholith deformed the earlier structures and in places resulted in considerable tectonic accumulation by intense folding and crumpling. Folds and thrusts are sharply deflected and locally converge into tightly compressed bundles near the earlier stocks, which acted as rigid buttresses.

MONZONITE RING DIKES ALONG THE MARGIN OF THE ANTELOPE CREEK STOCK, MONTANA

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U. S. Geological Survey, Washington, D. C.

The Antelope Creek stock is a roughly circular body of granodiorite about 5 square miles in area, lying 4 miles east of the northeastern corner of the Boulder batholith, Broadwater County, Montana. The stock is partly surrounded by a basalt sheet and by arcuate segments of monzonite ring dikes. All are intrusive into rocks of the Elkhorn Mountains volcanic rocks of Late Cretaceous age. Cenozoic deposits conceal the northeastern part of this intrusive complex as well as a postulated major fault separating the complex from Precambrian and Paleozoic rocks to the northeast.

The basalt sheet is the oldest unit of the complex and is probably contemporaneous with part of the Elkhorn Mountains volcanic rocks. It dips about 30° toward the stock and is as much as 600 feet thick. In places the sheet was cut and thermally metamorphosed by monzonite ring dikes which are similar in composition to and probably contemporaneous with some of the earliest rocks of the Boulder batholith. The dikes dip 65°–70° outward from the stock and are as much as 2200 feet wide. Both the sheet and dikes were intruded and thermally metamorphosed by granodiorite of the Antelope Creek stock. This granodiorite is similar in composition to and probably contemporaneous with the Unionville granodiorite of Knopf (1957), a major unit in the northern part of the batholith.

Faults of several ages are present; the older faults cut the basalt sheet and monzonite ring dikes but are truncated by the Antelope Creek stock; the younger faults cut all the intrusive rocks.

ULTRABASIC INTRUSIVE CONDITIONS ILLUSTRATED BY THE MOUNT ALBERT ULTRABASIC PLUTON, GASPE, QUEBEC*

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The Mount Albert pluton is a high-temperature ultrabasic mass 16 square miles in area, composed of dunite, peridotite, and minor enstatite pyroxenite. Its internal structure, based on peridotite-dunite banding, resembles the type of steep fold found in salt domes, and a similar intrusion mechanism is envisaged.

A metamorphic aureole up to 1000 feet wide borders the pluton on three sides. Aureole rocks range from greenschist through epidote amphibolite to garnetiferous hornblende-pyroxene granulite. The bulk chemical composition of the rocks shows no significant variation, although plagioclase becomes more calcic toward the contact. Changes in mineral composition appear to be due to redistribution of elements between coexisting minerals under high temperature-pressure conditions rather than to metasomatism.

The pluton illustrates the influence of water on the composition of the crystallizing mineral phases. Olivine (90–92 per cent forsterite) shows a minor variation. Small chemical variations are found in orthopyroxene (91–97 per cent enstatite) and large variations in chrome spinel (35–57 per cent in Cr_2O_3 and 10–32 per cent in Al_2O_3). High chrome-iron spinels and higher magnesian orthopyroxenes occur in the more serpentinized parts of the intrusion. This relation is interpreted as due to incorporation of water during intrusion, which influenced the pyroxene and spinel compositions by locally increasing the water-vapor pressure and effectively increasing the partial oxygen pressure. In areas of higher partial oxygen pressure, oxidation of Fe^{2+} resulted in crystallization of more magnesian orthopyroxene and iron- (and chromium-) rich spinel. These areas are irregularly distributed through the pluton and unrelated to primary banding.

COMPOUND EROSION SURFACE ON THE SAN FRANCISCO PENINSULA, CALIFORNIA

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The Buri Buri upland on the San Francisco Peninsula is a relatively narrow, northwest-trending, plateaulike surface, 22 miles long, along the northeast margin of the San Andreas fault. Its crest consists primarily of two adjacent geomorphic units: (1) a restricted, 5-mile-long, ½-mile-wide northern area of strikingly flat topography at about 600 feet elevation, cut on upper Pliocene-Pleistocene Merced and Jura-Cretaceous Franciscan rocks; and (2) a more extensive, 13-mile-long, 2-mile-wide southern area of rolling topography averaging 750 feet in elevation, cut on Franciscan and unnamed Paleocene-Eocene rocks.

General form and absence of evidence for other origins suggest that the rolling topography is probably a stream-eroded surface in late maturity. It postdates Paleocene-Eocene rocks, predates the Merced formation, and is probably Miocene or early to middle Pliocene in age.

The subjacent flat topography originated near sea level as an erosional modification of the rolling surface and consists of a series of coalescent stream-cut straths modifying the older, locally tilted surface which had previously been exhumed from beneath a lower Merced cover. Because the flat topography postdates lower Merced strata and predates a flanking sequence of marine terraces, the youngest of which apparently formed in Sangamon time, it is probably very late Pliocene or early Pleistocene in age.

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The upland crest is thus a compound erosion surface composed of two different topographies of distinct but related origin, history, and age.

EROSIONAL DEVELOPMENT OF BEACH CUSPS ALONG THE OUTER BANKS OF NORTH CAROLINA*

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The relation of conspicuously well-developed sand cusps to primary beach structures along the Outer Banks of North Carolina during a 9-month study indicates that they are solely the product of wave erosion of the lowest berm edge. Truncation of primary structures by cusp surfaces constitutes the fundamental evidence for erosive origin. Cusp surfaces consistently slope more steeply than the dip of beach laminae. Truncation is clearly demonstrated: (1) in cross sections cut in the cusps, (2) by the linear outcrops on the cusp surface of planar primary structures, and (3) by the measured loss of material from both horns and embayments during development. Failure of cusp points to migrate when subjected to oblique surf action is further evidence against their depositional origin.

The most typical sequence of events resulting in cusp development consists of: (1) steepening of the foreshore, (2) build-up on the foreshore of a narrow, elongate sand and gravel berm, (3) steepening the foreshore of this berm, and (4) concomitant with steepening, development of cusps by wave erosion of the berm edge.

Cusps are destroyed by: (1) gradual diminution in size of horn and enlargement of the embayment, (2) gradual to rapid trimming back of the horn, (3) partial burial by wind- or wave-laid sediments, or (4) a combination of these processes. Most commonly cusps deteriorate by gradual diminution during which they retain their identity for several days to 3 weeks.

ESTIMATE OF TOTAL DISPLACEMENT ON THE GARLOCK FAULT, SOUTHEASTERN CALIFORNIA

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A northwest-trending dike swarm in the Argus Range and Spangler Hills, north of the northeast- to east-trending Garlock fault, is correlated with a similar north-northwest-trending swarm in the Granite Mountains south of the fault. Although neither swarm can be traced into the fault itself, their projected intercepts are about 40 miles apart. The sense is left lateral.

North of the fault, the swarm is 10–20 miles wide and extends northward for at least 25 miles; it may be continuous with the upper Cretaceous (?) 85-mile-long swarm traced northwest from the northern Argus Range by Moore and Hopson (In press). The correlated southern extension is 12 miles wide and dies out 10 miles south of the fault. The dikes on the north side of the fault trend N. 40°–50° W.; the dikes on the south side trend N. 10°–20° W. Although the trends vary, both swarms intercept the curving Garlock fault at about the same angle; this suggests rotation of the faulted blocks. No other dike swarm having a comparable composition, trend, width, parallelism, or geologic age crops out along the fault.

The dikes in both swarms are composed predominantly of medium- to fine-grained dioritic or granitic porphyry. Most of the intruded rocks are quartz monzonite or granodiorite. The dikes are probably very late Mesozoic. Inasmuch as the Garlock fault was probably formed in early Tertiary time, the offset of the swarm presumably records the total offset of the fault.

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COMPLEX DISORDER OF H_2O MOLECULES AND Ca IONS IN WET-Ca CHABAZITE

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Following the determination of the Si, Al–O framework by Dent and Smith, the writer solved the crystal structure of hydrated Ca-chabazite at room temperture from two-dimensional [100] data giving R = 0.11. Atomic co-ordinates in R$\bar{3}$m with a 9.45 Å, alpha 94° 28′ are:

Atom	*Multiplicity*	*x*	*y*	*z*
Si, Al	12	.334	.1045	.8755
O_1	6	.025	.025	.324
O_2	6	.252	.252	.897
O_3	6	.262	.738	.000
O_4	6	.158	.842	.500
¼Ca	2	.200	.200	.200
¾H_2O_1	6	.244	.244	.571
½H_2O_2	3	.500	.500	.000
a	2	.415	.415	.415
b	6	.38	.62	.50

The framework has regular Si, Al-O distances and differs in shape from that of the dehydrated variety by as much as 0.5 Å. The positions of the H_2O molecules and the Ca ions are irregular, and not enough electron density is available to explain the chemical analysis. Probably site a is occupied by H_2O and site b by 0.1 Ca, but other distributions, including mixing of Ca and H_2O molecules, would be possible. Large vibrations of H_2O and b atoms occur and can be represented by pairs of positions at .230, .230, .585, .258, .258, .557 and .355, .586, .478—a 12-fold position—respectively. The highly disordered nature of the structure is consistent with the ease of ionic exchange and the nature of the nuclear magnetic resonance pattern.

ORGANIC, METAL-ION, AND CARBON DIOXIDE UPTAKE BY SEDIMENTARY MINERALS AND ITS SIGNIFICANCE IN THE MARINE ENVIRONMENT

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The removal of dissolved organic compounds, metal ions, and CO_2 from sea water by sedimentary minerals and their subsequent incorporation in sedimentary deposits is determined by environmental factors. Using controlled conditions in the laboratory, the writers conducted investigations on the effect of temperature, chlorinity, solution concentration, and mineralogy on this phenomenon. The writers conducted the studies by radiometric analysis, using carbon-14 labeled organic compounds, $C^{14}O_2$, Ca-45, Sr-90, and Cs-137.

The uptake of amino acids, dibasic acids, and carbohydrates is apparently dependent upon the molecular weight, structure, and functional groups present in each compound. An increase in chlorinity from 0 to 20‰ and an increase in temperature from 10° to 20° C. tends to decrease the uptake potential of the mineral. At lower solution concentrations the classical physical-adsorption phenomenon apparently occurs, followed by a linear increase in the organic uptake with increasing concentration. The uptake of the metal ions, calcium, strontium, and cesium at 20° C. for solutions of 0 to 20‰ chlorinity shows that increased chlorinity significantly depresses the uptake. In all instances the decreasing order of uptake was montmorillonite, illite, kaolinite, and quartz.

Carbon dioxide is also removed from solution by an apparent complexing with α-amino acids and

subsequent uptake by the clay minerals. This evidence suggests that mineral particles participate in the CO_2 system in the ocean and may act as a CO_2 reservoir.

CALDERAS: ASPECTS OF THEIR STRUCTURAL EVOLUTION AND THEIR RELATION TO RING COMPLEXES

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Detailed mapping of the Valles caldera, New Mexico, a 14-mile-wide depression formed by subsidence following the effusion of 50 cubic miles of ash-flow tuffs, has revealed a post-subsidence history of (1) rise of an elongate central structural dome transected by longitudinal and radial grabens, followed by (2) extrusion of a peripheral ring of volcanic domes. The structural dome and associated grabens are analogous to tectonic features of the Rhenish and Nubian-Arabian shields and indicate the action of positive vertical forces within the caldera following subsidence. Similar structural domes within the Creede caldera in Colorado, the Toba "super-caldera" in Sumatra, and other calderas indicate a common postsubsidence history for calderas differing greatly in size and in volume of associated ash flows. Extrusion of lava contemporaneous with faulting of the Valles and Toba domes suggests that doming was produced by intrusion of a central stock or laccolith.

Doming of the Valles caldera floor facilitated subsequent intrusion of magma along the caldera ring fracture and culminated in extrusion of the peripheral ring of volcanic domes. The relations suggest radial tension accompanying doming as an alternative mechanism to ring-fracture stoping for emplacement of ring dikes.

Comparison of the Valles, Creede, and Toba calderas with ring complexes in New Hampshire, Britain, Nigeria, and the Oslo region re-emphasizes the genetic relation of some ring complexes to calderas and suggests alternative interpretations for some subsidence features in ring complexes, especially those with interior grabens and/or central stocks.

PLUTONIC ROCKS OF THE SONOMA QUADRANGLE, NEVADA

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The bedrock structure and stratigraphy of the Sonoma quadrangle, Nevada, have been mapped admirably by Ferguson, Roberts, and Muller, but they reported little detail on the 30 plutons exposed, except for noting their position, outline, and general compositions.

With the advantage of this information, the writers studied the 30 plutons and drew the following conclusions. Compositions range from alaskite to diorite with random distribution. Sixteen show complexity of rock types. Country rock of many lithologies ranges from Cambrian to Triassic. Although the more basic plutons tend to favor younger sedimentary rocks there is no direct relation of composition to country-rock lithology. Textures are aphanitic (porphyritic) as well as granitic; the former are finer-grained near margins, and the latter are generally coarser-grained. The plutons are located in all kinds and types of structural and stratigraphic environments. They invariably crosscut bedrock with passive effect, except locally where the development may follow selected beds and structures. Twenty-three plutons cover less than 2 square miles each, and five cover 2–4 square miles. The area of two composite plutons exceeds 11 square miles. Hydrothermal mineralization is largely associated with aphanitic intrusive rocks.

The geographic position of the plutons is not determined by observable structure or stratigraphic controls. Horizontal size is limited to about 2–4 miles maximum. Plutons may be independent separate individual units not connected at depth. The emplacement was largely passive. Pluton development probably was a complex process and resulted in composite types when arrested before completion.

STRUCTURAL INTERPRETATIONS FROM AEROMAGNETIC DATA*

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The air-borne magnetometer survey of southeastern Pennsylvania has thrown new light on controversial structural interpretations.

Neversink Mountain, near Reading, consists of contorted Cambrian quartzite and Precambrian gneiss. The magnetic results indicate that this component of the Reading Prong is lacking a crystalline root, and this suggests a klippe. Thrusting may be a significant aspect of the complex Reading Prong.

Along the Martic Line no magnetic contrast exists between the Cambro-Ordovician sedimentary rocks and the adjacent albite-chlorite phase of the Wissahickon schist. There is, however, marked contrast in magnetic pattern between the albite-chlorite zone and the oligoclase-biotite zone of the Wissahickon formation. This indicates a gradational increase in metamorphism southward across the sedimentary rocks, the albite-chlorite schist, and the oligoclase-biotite schist, rather than a marked structural break at the Martic Line.

In the Baltimore gneiss north of Philadelphia, the northeasterly orientation of magnetic anomalies denotes pre-Appalachian structures whose strike markedly contrasts the more easterly trending Appalachian structures in the gneiss and adjacent Paleozoic sedimentary rocks.

In Chester County a large, elliptical area of anorthosite is rimmed by magnetic anomalies. This indicates an intrusive mass with a heretofore unsuspected border segregation.

These are a few examples which demonstrate that aeromagnetic mapping is a useful tool that goes far beyond finding ore bodies. In Pennsylvania it is helping to solve some long-standing structural problems and is revealing new, unsuspected structures.

CLEANING OSTRACODE VALVES WITH ULTRASONIC VIBRATIONS

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Ultrasonic generators can be used for disaggregating sediments that contain microfossils. This process has not been successful for the recovery of ostracodes, because vibration for the length of time necessary to disaggregate the sediment usually breaks the ostracode specimens. However, it has proved useful in cleaning individual specimens.

The specimen to be cleaned is covered with about a quarter of an inch of water in a small petri dish which is floated on the water in the ultrasonic transducer tank. Vibration from 30 seconds to a minute is usually sufficient to remove all matrix from valves, so that hinge and other shell structures can be examined. If incipient fractures are present, the specimens may break during even this short vibration time. Photographs of specimens before and after treatment will be exhibited.

LANDSLIDE DEBRIS FROM CRETACEOUS ROCKS IN THE WIND RIVER FORMATION OF EARLY EOCENE AGE, WIND RIVER BASIN, WYOMING

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In the southern part of the Wind River basin, Wyoming, several masses of debris from the siliceous Mowry shale (Lower Cretaceous) occur in the Wind River formation and are stratigraphically equivalent to some of the coarsest sediments of the Wind River. Most of the debris lies at the base of the

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Wind River formation on soft Cretaceous shale in a strike valley cut into rocks on the north flank of the Sweetwater Arch (Granite Mountains).

Fragments of shale ranging from small plates to segments of beds as much as 100 feet long lie in a belt of exposures 1.3 miles long. The exposures are as much as 2000 feet south of the nearest outcrops of the Mowry.

Most of the debris is at approximately the same altitude. The predominant dip of bedding in the debris is steeply northwest, in contrast to a gentle northward dip in the underlying Cretaceous rocks and a very slight southward dip in the enclosing Wind River beds.

The debris probably originated by landsliding from a ridge of Mowry shale during uplift of the ancestral Granite Mountains in Wind River time. Part of this ridge retreated a few hundred feet northward by erosion before being overlapped by Wind River sediments.

PROCESSES AND PRODUCTS OF COALIFICATION

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The fundamental processes operative in coalification are undoubtedly ordinary chemical processes, but until the metamorphosis of coal substances can be described in such terms, it appears useful to define the various processes by reference to the products yielded. In the development of a lithobody known as a coal seam, coalification processes are responsible for three important effects: (1) the development of maceral substances from detrital or attrital plant fragments, (2) the subsequent evolution of maceral substances, and (3) the concomitant metamorphosis of the lithotype material comprising the seam's constituent lithobodies.

Fusinization, vitrinization, and micrinization appear to be the major processes acting upon lignified source materials and their product macerals. Vitrinization is a multilinear process in which related macerals evolve in parallel or converging series. The products of these and other coalification processes can be classified effectively if macerals possessing similar chemical and physical properties are classed in the same maceral group, and if genetically related maceral groups are classed in the same maceral suite.

Coal lithotypes consist of natural aggregates of macerals and minerals so assembled as to give the mass a distinctive set of chemical and/or physical characteristics. Just as a grain of a particular maceral may evolve to be formed of another maceral, so a lithobody of particular lithotype composition may evolve and be composed of another lithotype.

A coal seam, then, is a composite of lithobodies that in turn are aggregates of lithograins, and these evolve in response to the chemical and physical factors operative in their environments.

URANIUM, SULFUR, IRON, AND MINERAL CONCENTRATIONS IN ORGANIC SEDIMENTS FROM SELECTED MARINE, BRACKISH-, AND FRESH-WATER ENVIRONMENTS

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Recent investigations of the swamp environments of southwestern Florida have yielded data concerning these depositional sites and their sediments. A mangrove forest occupies the marine sites and appears to be migrating inland and invading the extensive everglade environments that occupy brackish- and fresh-water sites. Both the mangrove and everglade environments include distinctive complexes of botanically and geologically recognizable sites in which organic sediments are accumulating. Inland migration of environments is being induced by the marine transgression occurring along the west Florida coast. Transgression is shown in pollen profiles through the recent sediment, in the

historical destruction of small islands, in the submarine extension of peat horizons, and in several other types of geological and botanical evidence.

Data derived from analyses of several cores show unexpectedly high concentrations of uranium at certain levels in the sediment. The uranium concentration is inversely correlated with the ash content and positively correlated with the carbon content. Thirty samples of surface sediment taken in a transect through marine, brackish- and fresh-water environments show a general decrease in uranium content with a decrease in proximity to the open sea. Sulfur concentration also appears related to sediment type and reaches magnitudes comparable to those in many Paleozoic bituminous coals. Although sulfur concentrations in dry peat in many cases exceed five per cent, no megascopically detectable pyrite has been observed. The sulfur content is positively correlated with carbon content. In the sediments studied, sufficient sulfur is present to account for the sulfide content of the average coal seam. The concentration of iron varies with the sulfur content, but the increase or decrease is not always proportional.

INSTANCE OF EVOLUTION IN THE CORAL *FLABELLUM*

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Rare "aberrant" growth forms of the Tertiary solitary coral *Flabellum* found in widely scattered localities are now known to be present in great numbers in New Zealand. This growth form, recorded from the Oligocene of California, the Miocene of Patagonia, and the Pliocene of Algeria and Sicily, has been regarded as an exotic abnormality, or in one instance as an example of geronticism. These coralla are adapted for life while lying on one side on the substrate rather than in the usual position with the base partially submerged in the substrate. A succession of these growth forms exhibiting increasing complexity begins in the middle Oligocene of New Zealand and ends in the late Miocene. Each of the stages of development has a morphological counterpart of approximately coeval age. Other specimens showing different adaptations for the same mode of life were apparently less successful and are short-lived. Upper Pliocene and Recent examples of a similar growth form are only the more primitive stages derived from different stocks. Alternative interpretations of the evidence are: (1) examples of polyphyletic adaptation which have no genetic relationship to an unstable substrate through long periods of time; (2) evolution of a selected stock which became adapted for this mode of life. If the latter is accepted, late occurrences of the growth form are interpreted as convergence. Progressive changes in the form of the corallum beyond basic modification necessary for life in a new position are considered as evolution with a trend toward an increasing size of the oral surface of the polyp. All occurrences of the coral in New Zealand indicate that it lived at various depths on an unstable bottom apparently in shallow-shelf seas, or at a change in bottom gradient where slumping of sediment might occur.

ASPECTS OF ION EXCHANGE IN ZEOLITES

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Ion-exchange values for natural samples containing certain zeolites are likely to be misleading if they are determined by standard procedures. Unlike some clay minerals in which the exchange reaction is completed in a short time, zeolites may take several months to complete the exchange reaction at room temperature; therefore standard procedures will give very low figures. The rate of exchange may be increased by heating; at 95° C. the exchange may take place more than three times as fast as at room temperature.

CHEMICAL STATE OF THE NITROGEN IN SEDIMENTARY AND IGNEOUS ROCKS

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A considerable amount of the nitrogen in sedimentary and igneous rocks exists as ammonium ions held within the lattice structures of silicate minerals. Analyses indicate that 10–66 per cent of the nitrogen in sedimentary rocks, and 33–91 per cent of that in igneous rocks, occurs as fixed ammonium. For sedimentary rocks, the fixed ammonium is associated primarily with illite clay minerals. Stony meteorites also were found to contain lattice-bound ammonium.

Low carbon-nitrogen ratios previously reported for sedimentary rocks were found to be due to fixed ammonium, a conclusion that emphasizes that the ratio should no longer be considered a characteristic of indigenous organic matter. Sedimentary rocks analyzed in this study had carbon-nitrogen ratios which ranged from 9.3 to 37.5; the carbon-organic nitrogen ratios ranged from 24.2 to 41.2.

Thus, a vast reservoir of nitrogen, estimated to be 20 times that present in the earth's atmosphere as elemental nitrogen, is contained within the lattice structures of silicate minerals. Nitrogen in the atmosphere originated, in part, through the release of fixed ammonium from igneous rocks during periods of intense volcanic activity.

EFFECT OF $LiAlSiO_4$ AND SiO_2 ON THE SEPARATION OF THE 131 AND $1\bar{3}1$ X-RAY-DIFFRACTION LINES OF SYNTHETIC ALBITE

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The influence of temperature, pressure, time, and size of starting material was described by MacKenzie (1957) for the separation of the 131 and $1\bar{3}1$ X-ray-diffraction lines of albite of intermediate structural state synthesized hydrothermally from Ab glass. MacKenzie's results were confirmed, and further experiments were made to determine the influence of two additional components, $LiAlSiO_4$ and SiO_2, on the 131-$1\bar{3}1$ separation of albite.

Contrary to expectations, intermediate albite synthesized from finely ground glass containing Ab, $LiAlSiO_4$, and SiO_2 components had a larger 131-$1\bar{3}1$ separation than albite crystallized under identical conditions from pure Ab glass. The relative abundance of the additional components under identical conditions did not affect the separation. The separation was similar, whether the additional components appeared as crystalline or liquid phases under the conditions of the experiment. The precise mechanism responsible for the larger separation has not yet been determined.

The 131-$1\bar{3}1$ separation of natural albite may reflect compositional variations of the environment, as well as the physical history of the albite. Therefore, data on natural albite may be inconclusive unless all the parameters involved can be evaluated.

TRANSCONTINENTAL ARCH—A MAJOR GEOLOGIC FEATURE OF NORTH AMERICA

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The transcontinental Arch has been called the "continental backbone," but its geologic significance is not generally appreciated. Various positive elements, such as Siouxia, the Colorado Plateau, Mazatzaland, and Mojavia, constitute essential portions and form a broad and reasonably continuous

belt. The arch extends from Labrador across the United States to the Pacific, a distance of at least 2400 miles. The trend is about N. 55° E. The arch may be visualized as an ancient promontory jutting southwestward from the continental nucleus. An age of 1400 million years is indicated.

The western portions are becoming better known and are the chief concern of this paper. In the early Paleozoic the filling of a large embayment between the arch and the shield commenced, and the eastward bulge of the Cordilleran geosyncline resulted. The filling of this embayment with igneous and sedimentary rocks is an important phase of continental growth. The Colorado and Arizona sags permitted shallow seaways to cross the arch at right angles. In the late Paleozoic the prominent folds of the Ancestral Rockies were superimposed at right angles upon the already elevated arch. During the Triassic and Jurassic the arch was a barrier between eastern and western seas, and much continental sediment accumulated upon it.

At present the arch is expressed by the trend of the southwestern arm of Lake Superior (N. 55° E.), by the outcrops of Sioux quartzite in the interior, by the porphyry belt of Colorado (N. 45° E.), by the dominant lines of fracturing in the Grand Canyon (N. 51° E.), and by the Las Vegas Line in southern Nevada (N. 47° E.).

MAGMATIC AND NONMAGMATIC ORES

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In prospecting, it is of importance to distinguish ores of magmatic origin from those derived by metamorphism and granitization of source rocks, and from those accumulated in certain sedimentary facies.

The magmatic ores are characterized by their occurrence along fault structures and may be associated with volcanic (including explosive) phenomena. Heat effects are local.

The magmatic sequence is well defined: kimberlite, with diamond pipes; ijolite, with carbonatites; peridotite, with nickel deposits; norite, with nickel-copper deposits; diabase-gabbro, with copper-zinc deposits. These deposits are characteristic of Precambrian shields, where thick sialic crusts may rest on basic to ultrabasic magmas.

In the Paleozoic terrains (in a broad sense) the sequence is resumed with monzonite porphyries and associated copper, copper-gold, and copper-lead-zinc deposits.

The monzonite and andesite intrusive rocks, with associated copper and copper-lead-zinc deposits, extend into the Mesozoic and Tertiary belts, where they have their greatest development. In some cases, as at Braden, Chile, the ores are found in explosive volcanic centers.

In Tertiary to Recent rocks, gold-silver telluride ores, mercury ores, and hot springs with sulfur deposition have developed—usually along lines of crustal weakness.

The above sequence represents decreasing depth, decreasing time, and decreasing temperature and conforms to Lindgren's temperature-depth classification.

The numerous nonmagmatic metalliferous provinces, in most cases, have little to do with crustal weakness and "main breaks;" prospecting principles applicable to magmatic ores may be misleading in these cases.

FORMULA OF SHATTUCKITE AND WEIGHT LOSS BY IGNITION

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The formula of shattuckite, determined by Schaller (1915), is $2CuSiO_3 \cdot H_2O$. Calculation from a new analysis of a shattuckite sample showed that this formula appeared to be correct, because it

was interpreted by the analyst that the loss of weight (6.31 per cent) of the shattuckite sample by ignition was caused by the removal of water. However, this loss of weight is caused partly by the removal of water and partly by the reduction of some CuO into Cu_2O. The reduction of CuO into Cu_2O begins at about 900° C., and a maximum loss of weight of 9.07 per cent is reached when the sample is ignited in a covered upright platinum crucible with a Meker burner (1200° C.) for 60 minutes. When the sample is ignited under the same condition for about 10 minutes, the loss of weight is about 6 per cent.

A dehydration study shows that the water content of the shattuckite sample is 3.71 per cent. Based on this water content, the formula of shattuckite is calculated to be $3CuSiO_3 \cdot H_2O$. According to this formula the possible maximum loss of weight by ignition of shattuckite is 9.61 per cent, 4.12 per cent by the removal of water, and 5.49 per cent by the reduction of CuO into Cu_2O. This is very close to the experimental results.

FLUORINE IN HAMBERGITE

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A chemical analysis of hambergite [$Be_2(OH, F)(BO_3)$] from the Little Three Mine, near Ramona, San Diego County, California, disclosed that the mineral from this new locality contains 6.0 per cent fluorine. Hambergite from a second California locality, the Himalaya Mine, near Mesa Grande, contains 0.5 per cent fluorine. Fluorine is not reported in analyses in the literature of hambergite from Madagascar, Norway, and Kashmir. A new analysis of Madagascar hambergite gave 1.0 per cent fluorine. No material was available for analytical work from Norway and Kashmir.

New data on hambergite from the Little Three Mine, California, and Imalo, Madagascar, follow: Madagascar—BeO 53.6, B_2O_3 (37.0), H_2O 8.8, F 1.0, less O = F 0.4, sum 100.0 per cent; orthorhombic, a_0 9.75 ± .01, b_0 12.19 ± .02, c_0 4.42 ± .01 Å; density 2.372 (calc.), 2.347 (obs.) gms/cm.³ California—BeO 52.9, B_2O_3 36.6, H_2O 6.7, F 6.0, less O = F 2.5, sum 99.7 per cent; orthorhombic, a_0 9.69 ± .01, b_0 12.32 ± .02, c_0 4.43 ± .01 Å; density 2.380 (calc.), 2.372 (obs.) gms/cm³.

Substitution of F for about half of the (OH) in the Little Three material causes the unit cell to expand in the b direction, while the a_0 contracts slightly and c_0 remains essentially the same. This is consistent with Zachariasen's structure (1931). The indices of refraction of fluorian hambergite from the Little Three Mine are lower by 0.011 for α and γ and 0.007 for β than the low-fluorine Madagascar material.

GRAVITY MEASUREMENTS ON HMS ACHERON IN SOUTH ATLANTIC AND INDIAN OCEANS

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About 40 gravity observations were made by means of Vening-Meinesz pendulum apparatus aboard the British submarine HMS ACHERON in the summer of 1959. Features over which the gravity measurements were made included the Walvis Ridge, the Continental Rise, Continental Slope, and Continental Shelf off Capetown, the Mozambique Channel, and the seismically active Mid-Indian Ridge. Over the Walvis Ridge the free-air anomalies are positive with respect to values on the Continental Rise on either side. A positive anomaly occurs at the edge of the shelf near Capetown and a negative anomaly on the slope and rise; this constitutes a typical gravity edge effect over a continental margin. In the Mozambique Channel the gravity values range from −60 to +30 mgal. It is unlikely that the structure beneath the channel is continental. Over the Mid-Indian Ridge the anomalies show large variations typical of gravity anomalies over Mid-Ocean ridges.

SCOLECODONTS FROM THE FORT RILEY LIMESTONE (WOLFCAMPIAN) OF KANSAS

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Samples were originally collected and processed by Stude and later by Stude and Tasch from three measured sections in the Fort Riley limestone. The maximum thickness of the exposure at the Augusta Quarry (NE sec. 9, T. 28 S., R. 4 E., Butler County, Kansas) is 40.5 feet. Insoluble residues of intrabiosparites and intrabiomicrites (Folk's classification) revealed the presence of scolecodont assemblages in many samples.

Twenty-five scolecodont zones were found in the lower 27 feet of section. Fifteen zones indicate restricted distribution on the Permian sea floor, since they cannot be traced around the quarry. Ten zones were traceable.

The fauna identified by Tasch consists of eight genera, six of which are known. Known genera include: *Leodicites, Staurocephalites, Ildraites, Nereidavus, Eunicites, Arabellites.* Known species include: *Ildraites anatinus* and three species of *Arabellites*: *A. falciformis, A. comis, A. hamiltonensis.* Several new species are present.

The youngest previously reported Paleozoic occurrence of scolecodonts was from beds of Early Mississippian age (Chouteau formation, Central Missouri). The present report extends this vertical range and indicates the likelihood that scolecodonts occur in many midcontinent Pennsylvanian and Permian limestones.

INTRUSION OF GRANITIC MAGMAS IN THE CORNUCOPIA STOCK, WALLOWA MOUNTAINS, NORTHEASTERN OREGON

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The Cornucopia stock contains two distinct tonalites of magmatic origin here denoted as units A and B.

Unit A was emplaced primarily by shouldering aside the country rocks, as indicated by marked deflection of structural trends, limestone compressed into S-shaped configuration, and flattened pebbles near intrusive contacts. Linear orientation of hornblende and planar structure are consistent with nearly vertical upward movement of magma. After emplacement, unit A differentiated into a marginal tonalite and a core of more felsic tonalite. Contours showing these changes in mineral proportions reflect modal analyses of two (2500 points each) large thin sections for each of 68 samples.

Unit B was emplaced relatively near the earth's surface where brecciation was more significant than plastic deformation. Miarolitic cavities are characteristic. Chilled contacts are best developed in a northern extension of the stock. Planar structure occurs but is not common. No obvious zonal relation is apparent from modal analyses of three (2700 points each) large thin sections for each of 29 specimens.

North of the Cornucopia stock, a separate intrusion of unit B has excellent chilled contacts, and dikes of tonalite porphyry have groundmasses too fine-grained for accurate modal analysis.

Although wall rocks and xenoliths are locally granitized, the Cornucopia stock is an exceptionally well-defined example of the emplacement of granitic magmas as manifested by textbook illustrations of nearly all features commonly associated with the intrusion of magma.

STRUCTURAL AND COMPOSITIONAL CHANGES DURING THE DEHYDRATION-REHYDRATION OF PHILLIPSITE AND RELATED SYNTHETIC ZEOLITE Na-P

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A natural phillipsite and synthetic Na–P phases with structures corresponding to Barrer's Na–P cubic and tetragonal phases have been studied. The loss of water on heating was measured under controlled P_{H_2O} conditions by using an automatically recording balance. Structural changes were followed by using an X-ray-diffractometer furnace with the same controlled P_{H_2O} conditions. Enthapy changes were recorded by D.T.A.

A weight-loss curve for the Na–P tetragonal phase shows two first-order discontinuities at 85° ± 5° and 118° ± 10°, and two second-order changes at about 158° and 278° C. Between these changes there appears to be a remarkably reproducible pseudoequilibrium composition for each temperature at a fixed P_{H_2O}. This implies a true solid-solution-like behavior between zeolite and water.

The structural changes are more complex. Below the lowest discontinuity in the weight-loss curve, a reversible phase transition occurs at 60° C. from the tetragonal (a = 10.12 Å, c = 9.85 Å) to an apparently cubic form (a = 10.0 Å). Between 85° and 360° three structural forms were identified. The structural changes correspond well with the discontinuities of the weight-loss curve except that a structural change could not be detected at 278° C. A natural phillipsite, initially orthorhombic, showed weight-loss discontinuities remarkably similar to that of the Na-P tetragonal phase.

O^{18}/O^{16} RATIOS IN ROCKS AND COEXISTING MINERALS OF THE SKAERGAARD INTRUSION OF EAST GREENLAND

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The Skaergaard intrusion of east Greenland is a gravitationally layered gabbroic mass that has undergone extreme fractional crystallization (Wager and Deer, 1939). Oxygen isotopic analyse have been obtained for the various rock types of this intrusion. Analyses have also been made of coexisting minerals from several of the layered differentiates and border-zone rocks. The general relationships among the O^{18}/O^{16} ratios of the minerals are the same as have been found in other igneous rocks. Plagioclase is higher in O^{18}/O^{16} than coexisting pyroxene, pyroxene is higher than olivine, and olivine is higher than magnetite or ilmenite. The O^{18}/O^{16} fractionations between minerals are somewhat smaller (0.4–0.5 per mil) in the Skaergaard rocks than in hornblende gabbros that have been studied. These differences are attributable to the differing crystallization conditions and higher temperatures of formation of the former. The later differentiates of the Skaergaard intrusion are progressively depleted in O^{18} to a marked degree relative to the rocks formed earlier. The late stage granophyres are 4–5 per mil lower in O^{18}/O^{16} than the layered hypersthene-olivine gabbros, and these granophyres have lower O^{18}/O^{16} ratios than any other igneous rocks yet analyzed (they are 8–9 per mil lighter than normal granitic rocks from other localities). This progressive depletion in O^{18} is a result of crystallization and settling out of minerals that are, on the whole, richer in O^{18} than the magma liquid. Calculations based on a simple crystallization model are in agreement with the experimental results.

METHOD OF STUDYING THE PHASE RELATIONS OF OXIDES OF THE TRANSITION METALS WITH SPECIAL REFERENCE TO THE SYSTEM FeO–Fe_2O_3–TiO_2

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Metals oxidize with a corresponding gain in weight. The extent of this oxidation depends on the temperature and the partial pressure of oxygen in the vapor over them. By measuring the gain in weight of metals as a function of oxygen partial pressure, at one temperature, the compositions and relations of the oxide phases can be determined. In practice, a sudden break in the slope of the curve representing the weight gain of metals with increasing oxygen partial pressure indicates a phase boundary. One curve gives the phase boundaries for the oxides of one particular metal or for a certain ratio of metals. Many such curves are necessary in order to obtain the compositions and oxygen partial pressures of coexisting oxide phases in systems of two or more metals. In addition to locating the phase boundaries, data obtained by this technique permit calculation of heats or reactions and estimation of ideality of solid-solution series. This technique has been applied to the system FeO–Fe_2O_3–TiO_2 at 1300° C., verifying the existence of ternary solid solutions between $FeO \cdot Fe_2O_3$ and $2FeO \cdot TiO_2$, between Fe_2O_3 and $FeO \cdot TiO_2$, and between $Fe_2O_3 \cdot TiO_2$ and $FeO \cdot 2TiO_2$. The first of these three solid solutions is the most nearly ideal, and the last is the least ideal. Conjugation lines, joining compositions of co-existing solid solutions, have been located.

SPURRITE FROM NORTHERN COAHUILA, MEXICO

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Spurrite occurs in contact-metamorphic rocks associated with several rhyolite stocks intrusive into Georgetown limestone in the Encantada district of Northern Coahuila, Mexico, approximately 50 miles southeast of the Big Bend National Park in Texas. The contact-metamorphic rocks include an inner spurrite-bearing calc-silicate-marble zone surrounded by an outer zone of marble; the metamorphic aureole reaches up to several hundred feet in width. The minerals of the calc-silicate-marble zone include spurrite, wollastonite, garnet, brucite pseudomorphous after periclase, rankinite, albite, tremolite, magnetite, manganiferous calcite; small patches of coarse-grained nepheline-sodalite-aegirine rock occur in a garnet-wollastonite-calcite rock which lies immediately adjacent to the rhyolite contact. The spurrite is concentrated on the outer side of the calc-silicate-marble zone in a coarse-grained rock in which crystals of spurrite several inches long have been found. The outer marble zone consists of a foliated manganiferous marble in which the foliation parallels the rhyolite contacts; braunite and hausmannite occur in this rock.

The spurrite-bearing contact-metamorphic rocks are found associated only with rhyolites which solidified within the thick Georgetown limestone. Rhyolites which penetrated through the Georgetown limestone have a sharp contact with the limestone and show no contact-metamorphic effects.

CLAY MINERALOGY OF THE CORDILLERAN AND KEEWATIN TILLS IN THE VICINITY OF CALGARY, ALBERTA, CANADA

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Investigation of the Pleistocene succession in the vicinity of Calgary, Alberta, revealed five tills, two Cordilleran tills deposited by glaciers originating in the Rocky Mountains west of Calgary,

two Keewatin tills deposited by ice originating north and east of Calgary, and one "hybrid" till derived from Cordilleran and Keewatin sources.

Because the clay-mineral suite of these tills indicates source and direction of ice movement, it is a valuable stratigraphic tool. Montmorillonite, the principal clay mineral of the Keewatin tills, was derived from Mesozoic and Cenozoic rocks, whereas illite, the principal clay mineral of the Cordilleran tills, was derived largely from Paleozoic rocks.

The clay mineralogy of 74 samples of till was determined by X-ray diffraction. The Keewatin tills contain 46 per cent montmorillonite, 39 per cent illite, and 15 per cent chlorite-vermiculite-kaolinite. The clay-mineral content of the Cordilleran tills depends on their proximity to the Rocky Mountains. Because the mountains west of Calgary are composed largely of Paleozoic rocks, montmorillonite is rare. Near the mountain front till contains 5 per cent montmorillonite, 74 per cent illite, and 20 per cent chlorite-vermiculite-kaolinite. Glaciers moving eastward from the mountains passed over and incorporated montmorillonite-rich Mesozoic rocks. Thus, 40 miles east of the mountains the Cordilleran till contains 21 per cent montmorillonite, 62 per cent illite, and 17 per cent chlorite-vermiculite-kaolinite. The "hybrid" till contains 34 per cent montmorillonite, 49 per cent illite and 17 per cent chlorite-vermiculite-kaolinite.

BASE METALS IN BIOTITE, MAGNETITE, AND THEIR ALTERATION PRODUCTS IN A HYDROTHERMALLY ALTERED QUARTZ MONZONITE PORPHYRY SILL, SUMMIT COUNTY, COLORADO

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Fresh and altered facies of a quartz monzonite porphyry sill in the Breckenridge mining district, Colorado, contain trace amounts of copper, lead, and zinc. In both facies, these metals are in the iron-rich minerals, where they are concentrated in proportion to the iron content of the host mineral. In the unaltered rock, the base metals are in the magnetite and to a lesser degree in the biotite. Upon alteration, biotite was replaced progressively by iron-rich chlorite, iron-poor chlorite, and finally muscovite. The base-metal content of the micaceous minerals decreases through this sequence. Magnetite remained stable in most of the altered rocks, but where alteration was extreme it was replaced by pyrite, which in turn was altered to hematite. The base-metal content of the magnetite varies little, and in most of the altered rocks hematite derived from it contains about the same proportions. Near strongly mineralized areas, however, the rock is enriched in base metals, most of which are in the hematite. Some base metals were added to the chlorite, but little was added to the muscovite.

MISSISSIPPIAN SEDIMENTATION AND STRATIGRAPHY OF SOUTHEASTERN ARIZONA

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Marine Mississippian carbonate rocks ranging from an edge to more than 1550 feet thick rest conformably (?) on Devonian and disconformably underlie Pennsylvanian strata in southeastern Arizona. The section thickens southeastward along a line trending through the Gunnison Hills and Pedregosa Mountains.

The Escabrosa limestone ranges from Early Kinderhookian (?) to Early Meramecian age in southeastern Arizona; northward the uppermost beds are Osagian. It is divisible into three members traceable over most of the area. The lowest member consists of about 525 feet of massive dolomite overlain by fine-grained limestone; northern sections have a basal sandstone unit. The middle member consists of about 235 feet of thin-bedded, cherty limestone which grades eastward into shale and

northward into brecciated, oölitic limestone. The top member consists of approximately 515 feet of encrinite which becomes more cherty northward.

The Black Prince limestone, disconformably overlying the Escabrosa, consists of about 170 feet of basal red shale, overlain by thin-bedded limestone. The Paradise formation, conformable in most places with the Escabrosa, consists of approximately 290 feet of fossiliferous shale and limestone. Both formations are of Meramecian and Chesterian ages and may represent equivalent facies deposited in interconnected basins.

The transgressive Escabrosa was deposited with brief interruptions in a subsiding northwest-southeast-trending basin. Uplift of a northern shelf and a southwest-trending prong began in late Early Mississippian. Erosion produced karst topography, and residual red shales developed on the Escabrosa. Deposition probably ceased by Chesterian time in the northwest Black Prince basin but continued in the southeast Paradise basin.

RATE AND TREND OF CARBONATE DIAGENESIS

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The inner ostracum of the last-deposited segment of a modern clam consists of two layers. Internal structures are simple, and boundaries between the two are well defined.

In older segments, the featureless nacreous layer has crystals less than 1 micron in size; next above occur surface parallel laminations of 2–4 microns. Upon this is eventually superimposed a set of transverse crystals, which increase in size and number before merging with the prismatic layer. The latter crystals extend, without interruption, across former nacreous laminae.

Differences in amount and organization of conchilion, as well as ordering of the shell calcite, are present. These differences are interpreted to represent diagenetic changes. The specimens were collected alive; therefore, reformation is rapid, probably starting immediately after deposition of constituent materials.

A hand specimen of Mariana limestone (Oligocene) was subjected to 344 cycles of wetting and drying at near-surface temperatures and pressures.

The number of total pores-per-gram samples increased from a minimum, at the size of 1 micron, to a maximum of 5 per cent in the .3 micron size, gradually diminishing to 2 per cent in the 0.04 micron size.

The growth of calcispheres, dog-tooth cavity fillings, as well as loss of definition of boundaries between fossils and matrix, occurred.

The reformation of calcareous material of fossil fragments apparently begins by diminution of crystal sizes, followed by gradual agglutination, or enlargement into grains with better optical continuity. Significant mineralogic changes were not noted by X-ray analysis.

CRUSTAL STRUCTURE AND CENOZOIC DEFORMATION IN THE BASIN AND RANGE PROVINCE

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During the latter part of the Cenozoic era the crust in the Basin and Range Province has been thickening, and expanding laterally, and the general altitude has been increasing. Seismic measurements show that the crust (defined to include all material down to normal mantle of velocity 8 km/sec. or more) is anomalous in having a thick lower part with seismic properties closer to mantle than to ordinary crust. A thickened crust, inferred from the principle of isostasy, is supported by recent measurements of gravity. Much of the regional upwarp and also its isostatic compensation in

the lower part of the crust has occurred since early Pliocene time, for Pliocene sedimentary rocks contain fossil evidence that they were deposited at much lower altitudes than where they now lie. Horizontal components of strain during the same period, indicated by the geologic record and by recent deformation, strongly suggest that the area has been expanding.

Mantle rock seems to have been changed progressively into crust, with both vertical and lateral expansion. Riding upon the expanding material, the upper part of the crust spread laterally, broke into blocks, and was further deformed by igneous activity and by strike-slip faulting. Of two hypotheses for the change of mantle into crust, eclogite → basalt is preferable to peridotite → serpentine because the eclogite conversion is favored by a high geothermal gradient, inferred from volcanism which characterizes this and other regions of block faulting.

EFFECT OF Cu ON SPHALERITE PHASE EQUILIBRIA—A PRELIMINARY REPORT

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Preliminary experiments in the system Cu–Fe–Zn–S show that sphalerite in equilibrium with pyrite, pyrrhotite, and chalcopyrite at 666° C. and the vapor pressure of the system has the approximate composition $Zn_{0.818}Fe_{0.17}Cu_{0.018}S$, corresponding closely to the Zn/Fe ratio reported by Barton and Kullerud for sphalerite in equilibrium with pyrite and pyrrhotite in tht system Fe-Zn-S under similar conditions. The data at hand thus suggest that the presence of chalcopyrite has little effect on the sphalerite geothermometer.

Most analyzed sphalerites from the Central City district, Colorado, have compositions falling within the experimentally determined stability field of sphalerite; the shape of the field is similar to that predicted on the basis of natural occurrences in that most of the sphalerite field is bounded by fields representing assemblages in which chalcopyrite is a stable phase. Thus contraction of the sphalerite field with falling temperature should result in exsolution of chalcopyrite more commonly than in exsolution of pyrrhotite, in agreement with the relationships observed in natural ores.

Solid solution of CuS in iron-free sphalerite seems to be very small (< 0.5 per cent) at temperatures up to 600° C. Substitution of Cu in an Fe-bearing sphalerite decreases the cell edge but apparently never below the value for pure ZnS.

INCLUSIONS IN THE PRECAMBRIAN GNEISS OF THE CARNEY LAKE COMPLEX, DICKINSON COUNTY, MICHIGAN

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The Carney Lake complex of southern Dickinson County, Michigan, consists chiefly of Lower Precambrian gneiss that contains inclusions of amphibolite, biotite schist, and metasedimentary rocks. The distribution and field relationships indicate that the amphibolite and biotite schist are metamorphosed remnants of basalts which covered this area prior to the formation of the gneiss. In addition, the biotite schist contains remnants of amphibolite; the amphibolite and biotite schist exhibit relict diabasic texture; the hornblende of the amphibolite is pseudomorphous after pyroxene; chemical analyses of the amphibolite are very similar to those of basalt; standard rock-cell equations indicate that only silicon, potassium, and sodium are needed to convert the amphibolite to biotite schist; and the amphibolite is characteristically associated with tonalitic gneiss, whereas the biotite schist is associated with a composite gneiss which consists of tonalitic gneiss which exhibits later, megascopic and microscopic layers of quartz, microcline, and albite.

The inclusions of metasedimentary rocks, now vitreous quartzite, sericitic quartzite, and quartz-biotite schist, are clearly remnants of the pregneiss cover which apparently consisted of both sedi-

mentary and volcanic rocks. Furthermore, the inclusions resemble groups of rocks which exhibit the proper stratigraphic relationships, consist essentially of metasedimentary and metavolcanic rocks, and occur almost immediately to the north, northeast, and south of the complex.

APPLICATION OF PALYNOMORPHS FOR THE RECOGNITION OF FACIES IN THE UPPER CRETACEOUS—LOWER TERTIARY OF COLORADO AND WYOMING

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Palynology can assist in the recognition and interpretation of facies. For example, an abundance of *Rhizophora* pollen in a sediment would be direct evidence for the presence of a mangrove swamp and therefore of a shore-line deposit. However, most pollen and spores originate from the land flora adjacent to a depositional site and hence are usually useless as direct indicators of facies. Accessory organisms encountered in palynological preparations—organisms which are indigenous to the depositional site—are extremely useful in the interpretation of facies. Fluviatile or lacustrine deposition can be recognized by the presence of such algae as *Botryococcus* and *Pediastrum*. The fern *Azolla* and Cookson's "megaspores" are also undoubted fresh-water organisms. Brackish or deltaic deposition can be inferred from the presence of certain hystrichosphaerids, and by a mixture of fresh-water and saline organisms; brackish to saline deposition can be inferred by the presence of microforaminifers, hystrichosphaerids, and dinoflagellates.

Less reliable facies inferences can be derived from the interpretation of size and abundance of palynomorphs present in a sediment. Uniform small size and low concentration suggest a mid-basin or offshore deposit; abundance, large size, increase in fungus spore and cuticle content, or the presence of fusain fragments strongly suggest near-shore deposits.

Examples of occurrence of the above facies indicators are discussed in relation to the following formations in Colorado and Wyoming: Wind River, Wasatch, Fort Union, Lance, Lewis, Meeteetse, Mesaverde, Iles, Williams Fork, and Mancos.

SEISMIC INVESTIGATIONS IN THE CONNECTICUT RIVER VALLEY, SOUTHERN MASSACHUSETTS

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Seismic studies in the Connecticut River valley near Longmeadow, Massachusetts, along a 5-mile east-west line were conducted in 1957 and 1958. The bedrock in this area is the Longmeadow sandstone of Triassic age, which has an average velocity of 13,000 fps and is an arkosic sandstone and shale. The bedrock is overlain by glacial till, varved clay, and proglacial outwash, which have an average velocity of 5000 fps. Above these are eolian deposits and alluvium with an average velocity of 1200 fps.

The seismic profile indicates that the present course of the Connecticut River, which in this locality lies on bedrock, is more than 2500 feet west of the preglacial course of the Connecticut. The abandoned trench has been cut in bedrock to at least 40 feet below present sea level and may correlate with the trench 100 feet below sea level described by Cushman (1960) in Connecticut. Borings taken 3 miles north of the profile indicate a bedrock surface more than 118 feet below sea level.

The bedrock surface east of the preglacial Connecticut River valley rises irregularly to about 140 feet above sea level in 3.5 miles, where it is cut by a 60-foot trench that may represent a tributary to the ancestral Connecticut River.

PRECAMBRIAN ANCESTRY OF THE COLORADO MINERAL BELT

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The narrow northeast-trending Colorado Mineral Belt is characterized by intrusive porphyries and associated ore deposits of Laramide age and in some places by faults of northeasterly trend. The belt—about 250 miles long—extends diagonally across the generally north-trending mountain ranges of the State, occupies several different geologic environments, and seems to be independent of the present mountain structure.

The Mineral Belt follows an ancient zone of weakness defined by northeast-trending shear zones of Precambrian age in a belt 10–35 miles wide. Individual shear zones or clusters of zones are spaced unevenly within this belt, from a mile or less to many miles apart, and are arranged en echelon.

Movement occurred along the belt of shear zones through most of the Precambrian time recorded in the region. During this span of time, deformation progressed from a deep-seated environment characterized by folding and plastic flow to a more shallow environment characterized by cataclasis, retrograde metamorphism, and fracture.

Movement within the regional zone of shearing continued sporadically and on a minor scale during Paleozoic and Mesozoic time, as shown by stratigraphic features of several sedimentary formations along the zone. With the onset of the Laramide orogeny, magma invaded the regional zone of shearing and imparted to it the conspicuous features that characterize the Mineral Belt—intrusive igneous bodies and ore deposits. Fault movement took place along the zone at this stage also but was on a smaller scale than it had been previously.

GLACIAL GEOLOGY OF BURIED BEDROCK VALLEYS OF THE NEW ENGLAND COAST

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Test borings for bridges crossing 14 New England rivers or bays near the coast (including Narragansett and Passamaquoddy bays) reveal information on depth to thalwegs of buried bedrock valleys and on nature of contained unconsolidated sediments.

Minimum elevations of buried thalwegs range from about −90 feet msl (mean sea level) to about −400 feet msl. Identification of erosional levels is uncertain, but they may occur at about sea level, at −200 to −250 feet msl, and possibly at −400 to −450 feet msl. These valleys were formed before the Wisconsin glacial stage, and the thalweg elevations are not a measure of sea-level decline at Wisconsin maximum. The present position of the valleys below sea level may be largely due to crustal movements independent of glaciation.

Unconsolidated deposits within the bedrock valleys differ systematically along the coast. In the Connecticut valleys, fluvioglacial outwash, possibly related to the Middletown ice stand, is trenched by valleys that are in turn filled with estuarine deposits to about present sea level. Valleys in the Boston area and southern Maine contain mainly glacial-marginal marine clays, also overlain unconformably by estuarine deposits. The deposits in Narragansett Bay have elements of both sequences. The estuarine deposits are believed to represent the last major eustatic rise of sea level. The underlying unconformity, however, may have originated from one or more of several causes. Correlation between the outwash in the Connecticut valleys and glacial-marginal marine clays elsewhere depends upon tracing of Wisconsin drift borders across New England.

PYROLYSIS OF AMINO ACIDS IN AQUEOUS SOLUTION

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Aqueous solutions, each containing equimolar amounts of six amino acids, were pyrolyzed in sealed, evacuated, Pyrex tubes at 230°C. for varying periods of time using one-dimensional paper chromatograms for determination of the rate of decomposition.

The hours required to halve the initial concentration (0.01 molar) of each amino acid in mixture I were: 240 (glutamic acid), 40 (alanine), 24 (glycine), <24 (proline), <24 (leucine), and ≪24 (aspartic acid). The corresponding times in hours for mixture II were: 55 (gamma-aminobutyric acid), 16 (alanine), 1 (phenylalanine), <1 (serine), <1 (threonine), and ≪1 (aspartic acid). In the presence of increasing concentrations of glucose, the breakdown of alanine is accelerated. The above data show that the decomposition kinetics of a given amino acid can be strongly influenced by the presence of other organic compounds. With the exception of aspartic acid there is a parallel between the thermal stabilities of the amino acids and their presence in geologic deposits of increasing age.

A method is outlined for calculating the maximal continuous temperatures that given deposits could have been subjected to, on the basis of the amino acids present. The maximum continuous temperature for the Green River shale was calculated to be 74° C.

GEOLOGISTS VERSUS THE FOREIGN LITERATURE

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For reasons of cost, time, and accuracy it would be desirable for geologists to be able to read foreign literature in their specialties in the original language rather than depend entirely on translations, but in spite of language requirements for advanced degrees few at present ever attain adequate proficiency to do so. Language requirements would acquire real significance if students were encouraged to study languages as early as possible and to make it a habit to use them in connection with geology courses. It is up to geology teachers to devise means of implanting that habit.

GEOLOGIC AND GRAVIMETRIC STUDY OF BASIN AND RANGE DEFORMATION IN INDIAN WELLS VALLEY, SOUTHEASTERN CALIFORNIA

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Indian Wells Valley is a 400-square-mile structurally depressed basin filled with Cenozoic sedimentary rocks. In the mountain ranges which encircle it and expose plutonic and metamorphic rocks of the Sierran batholith, a pre-Basin and Range structural system is delineated by five parallel fault zones in which individual faults are up to 18 miles long, by dike swarms, and by foliation. These structures trend northwest and are cut by two extensive Basin and Range fault zones in which a series of faults form steps descending from the mountain uplands into the basin. Concealed parts of these fault zones are inferred from gravity-anomaly contours controlled by 1380 gravity measurements which are corrected for the effects of elevation, terrain, latitude, and regional gradient.

The northern and southern closure of the basin is largely caused by renewed displacement along pre-Basin and Range faults during the Basin and Range deformational period. Minor left-lateral separation along some Basin and Range faults is overshadowed by large dip separation.

FAUNAL DISTRIBUTION IN THE CRETACEOUS FOX HILLS FORMATION

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The youngest ammonoid-bearing deposits of the interior Cretaceous are included in the Fox Hills formation in and north of its type area in north-central South Dakota and adjacent North Dakota. These deposits contain four principal lithologic facies that intergrade vertically and laterally with their adjacent facies and appear to represent distinct marginal marine environments. Lateral differences in fossil assemblages within individual facies reveal significant environmental changes otherwise masked by the gross lithologic uniformity.

Characteristic buff-weathering sand within the Fox Hills in the Grand River valley and northward contains a sparse fauna dominated by the pelecypod *Tancredia*, whereas in the Moreau River valley and southward the same sand contains a rich marine fauna characterized by *Idonearca*.

In the basal, dominantly silt and clay facies of the Fox Hills macrofossils occur in calcareous concretions distributed in persistent thin zones. Each fossiliferous concretion zone contains a diagnostic molluscan assemblage that commonly consists of great numbers of one species of pelecypod and a variety of other mollusks. Exceptions include zones in which ammonoids or gastropods dominate. Certain fossiliferous zones cover large areas as much as 85 miles in long diameter, but each zone undergoes abrupt faunal change westward, presumably shoreward. The total aspect of these fossiliferous concretion zones favors the hypothesis that each represents a catastrophic mass killing with little subsequent transport of the shells. Community distribution and lateral changes in biofacies are shown best by pelecypods, but somewhat similar patterns of distribution are also shown by certain ammonoids.

P-T STABILITY CURVES OF REACTIONS IN THE SYSTEM CaO-MgO-SiO_2-CO_2 AND GEOLOGICAL APPLICATIONS

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The P-T equilibrium curve has been experimentally determined for the reaction:

I. 2 monticellite + 1 spurrite = 2 merwinite + 1 calcite.

The reaction occurs at 820° C., 15 psi, and has a slope of −0.7° C./1000 psi.

The mineral assemblages at Crestmore, California, are interpreted in the light of the above experimental results and those previously obtained for the reactions:

II. 1 diopside + 1 forsterite + 2 calcite = 3 monticellite + 2 CO_2,

III. 1 diopside + 1 calcite = 1 akermanite + 1 CO_2,

IV. 3 monticellite + 1 diopside = 2 akermanite + 1 forsterite,

V. 1 forsterite + 1 calcite = 1 monticellite + 1 periclase + 1 CO_2.

The P-T curves for reactions II, III, and V all pass through 800° C./2500 psi CO_2, 885° C./6000 psi CO_2, and 925° C./10,000 psi CO_2. The P-T curve for reaction IV passes through 885° C. at 6000 psi and has a slope of 4° C./1000 psi.

The coexistence of merwinite and calcite locally in the outer (monticellite) zone indicates that the conditions of reaction I (820° C.) were attained. The coexistence of monticellite and diopside in the intermediate (idocrase) zone indicates that the conditions of reaction IV (ca. 885° C.) were not attained there. The quartz monzonite porphyry which caused metamorphism is thus indicated to have been between 850°–900° C. at the time of emplacement.

The widespread coexistence of spurrite and monticellite in the monticellite zone indicates that the temperatures there generally were below 820° C. Under these conditions, spurrite is stable only at

CO_2 pressures below 1000 psi. However, the coexistence of calcite and diopside (reaction III) in the idocrase zone indicates that the CO_2 pressure increased toward the intrusive.

LEAKY ARTESIAN AQUIFER CONDITIONS IN ILLINOIS

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The vertical permeability of confining beds often can be determined from the results of pumping tests by using the nonsteady-state leaky artesian equation derived by Hantush and Jacob (1955). A time-drawdown-type-curve method for analyzing pumping-test data with that equation is described in detail. This method is applied to available pumping-test data for Illinois. A summary of the results of leaky artesian test data collected to date indicates that the vertical permeability of glacial drift deposits in the southern half of Illinois ranges from 0.08 to 1.6 gpd/sq.ft.

A form of Darcy's law is applied to data on the piezometric surface of the Cambrian-Ordovician aquifer to determine the vertical permeability of the Maquoketa formation. The Maquoketa formation has an average thickness of 250 feet, consists largely of shale, and confines water under artesian conditions in the Cambrian-Ordovician aquifer. The Cambrian-Ordovician aquifer occurs at an average depth of 500 feet below Chicago, has an average thickness of 1000 feet, consists mainly of sandstone and dolomite, and is the most highly developed source of large ground-water supplies in northeastern Illinois. Computations indicate that the average vertical permeability of the Maquoketa formation is about 0.00005 gpd/sq. ft. Leakage in 1958 through the Maquoketa formation in northeastern Illinois is estimated to be about 8,400,000 gpd (gallons per day) or about 11 per cent of the total amount of water pumped from deep wells.

ISOTOPIC COMPOSITION AND CONCENTRATION OF LEAD IN SOME CARBONATE ROCKS

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The isotopic composition of lead in carbonate rocks may reflect that of the ocean from which they were deposited. Lead abundances were determined on selected samples by isotope dilution, using a Pb^{208} spike. Most of the samples were recrystallized Precambrian calcites and dolomites, which had 0.4–1.4 ppm lead. Shells of several modern marine organisms showed only about 0.2 ppm lead.

In most cases the 208/204 ratio of the lead in the sample could be determined during the isotope-dilution run. The Pb^{208}/Pb^{204} ratios from the Precambrian samples (range: 34.03–36.01) compare favorably with those of "normal" lead minerals of similar age. These values, as well as several complete isotopic analyses, suggest that the lead in the ancient carbonates when corrected for the radiogenic lead produced from incorporated uranium is isotopically similar to "model" lead of the crust at the time of deposition of the rocks. The original lead in the carbonate rock, however, may be contaminated with radiogenic lead from the environment.

AUSTRALIAN COAL

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Commercial coals occur in Permian, Triassic, Jurassic, Cretaceous, and Lower Tertiary rocks. Permian coals are mined in New South Wales, Queensland, and Western Australia, Triassic in New South Wales, Queensland, Tasmania, and South Australia, Jurassic in Queensland and New South

Wales, Cretaceous in Queensland. Early Tertiary brown coals are mined in Victoria. Thus, all six Australian states have commercial resources.

Permian coals are in the Greta (Leonardian) and Tomago and Newcastle (Guadalupian) measures. They differ from American Paleozoic coals in thickness (50 feet, New South Wales; 110 feet, Queensland), in the absence of underclays, and in having partings of bentonites in a few places. Thicknesses of individual beds are variable, although the beds are regionally persistent.

Triassic coals are most valuable in the Leigh Creek basin, South Australia, where one bed is commonly 40 feet thick. In Queensland and New South Wales they are highly variable and commonly possess bands of impurities.

Jurassic and Cretaceous coals are generally thin and so variable as to be unimportant except locally in southern Queensland.

Tertiary brown coals are found in southern Victoria both east and west of Melbourne and are of extraordinary thickness. One boring has recorded successive coals with thicknesses of 299, 366, 97, 70, 60, and 35 feet listed in descending order. Strip mining of more than 100 feet is carried on at Delorme (500 feet) and Bacchus Marsh. The coals are believed to have been estuarine accumulations along the borders of an Early Tertiary sea.

RELATION OF MINERAL SPRINGS TO PERMIAN SALT

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Salt springs in northwestern Texas and western Oklahoma occur in a broad northeastward-trending band which coincides with the outcrop of upper and middle Permian rocks. The line of springs is interrupted in western Oklahoma by the trough of the Anadarko syncline. The chloride concentration of the water ranges from about 20,000 ppm to more than 200,000 ppm.

Studies in progress show that the source of salt in the spring water is halite in middle and upper Permian rocks. The salt is disseminated in shale or forms almost pure beds of halite. At some localities salt is a minor constituent in beds of gypsum and dolomite. In many places salt beds are within 150 feet of the surface, and in a few places salty shale crops out.

Contour maps on the top of the salt demonstrate that "lows" are developed in saliferous deposits in the vicinity of salt springs. Also, most of the springs are near the sharp eastern edge of salt deposits. The east edge of the salt in many places is too sharp and steep to be explained by any process of deposition; therefore, it must have been formed by solution. Solution of the subsurface salt is indicated also by other phenomena, such as solution and collapse features at the surface along the eastern margin of the salt.

TENSILE STRENGTH OF NaCl ICE

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To resolve some of the factors causing strength variation in natural sea ice, fresh water and five different $NaCl$-H_2O solutions were frozen in a tank designed to simulate the one-dimensional cooling of natural bodies of water. The resulting ice was structurally similar to lake and sea ice. The salinity of the salt ice ranged from 1‰ to 22‰. Brine-volume tables and densities were computed for these salinities in the temperature range 0° to −35° C. The ring-tensile strength (σ) of fresh-water ice was found to be essentially temperature independent, with an average value of 28.7 ± 5.5 kg/cm² in the temperature range −10° to −35° C. A slight decrease in strength was observed at −5° C. The strength of salt ice at temperatures above the eutectic point (−21.2° C.) significantly decreases with brine volume (ν); $\sigma = 24.71 - 5.15\sqrt{\nu\%}$. The σ axis intercept of this line is in the range of the σ values determined for fresh-water ice; this indicates that there is little, if any, difference in stress

concentration between sea and lake ice as the result of the presence of brine pockets. The strength of ice containing $NaCl \cdot 2H_2O$ is identical with the strength of fresh-water ice and is independent of the volume of solid salt and the ice temperature. No evidence was found for the existence of either phase or geometric hysteresis in NaCl ice. The strength of ice at subeutectic temperatures, however, is decreased appreciably if the ice has been subjected to temperatures above the eutectic point. This is the result of redistribution of brine in the sample during the warm-temperature period. The present study is in agreement with published data from natural sea ice and indicates that reinforcement of brine pockets by $Na_2SO_4 \cdot 10H_2O$ is either lacking or much less than previously assumed.

EQUIVALENCE OF THE PRECAMBRIAN IDAHO SPRINGS FORMATION AND THE QUARTZITE ALONG COAL CREEK, FRONT RANGE, COLORADO

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Stratigraphic correlation, metamorphic grade, and structural history indicate that the quartzite along Coal Creek is a lithologic variant of the high-grade metamorphic Idaho Springs formation, rather than a younger rock of lower grade as previously described.

One of three schist layers in the quartzite has been traced laterally into schists, gneisses, and lime-silicate rocks of the Idaho Springs; this indicates an equivalence in age and an abrupt sedimentary facies change. All the metasedimentary rocks, including the quartzite, are intruded by and therefore are older than the Boulder Creek batholith and associated quartz monzonite.

Early staurolite that crystallized in the schist layers during formation of microfolds was replaced by andalusite during a period when andalusite and cordierite crystallized poikiloblastically. The microfolds outlined by quartz and opaque minerals are preserved inside the poikiloblasts. The staurolite, andalusite, and cordierite plus garnet, sillimanite, epidote, tremolite, and hornblende indicate high-grade metamorphism characteristic of the Idaho Springs formation.

Three periods of structural deformation and metamorphism are recognized: (1) early folding with regional metamorphism of staurolite grade, (2) later folding which formed the Coal Creek syncline with syntectonic intrusion of the Boulder Creek batholith and quartz monzonite and thermal metamorphism indicated by the crystallization of cordierite and andalusite, and (3) intense cataclasis without notable retrogression, in a persistent zone south of Coal Creek. Structural features of the quartzite and the adjacent rocks of the Idaho Springs are similar. The last two deformations are similar to the two periods of deformation recognized in the Idaho Springs-Central City area.

PRECAMBRIAN AGE MEASUREMENTS IN FINLAND

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New K–Ar, Rb–Sr, and isotopic zircon age measurements are in agreement with the earlier discovery that the Karelidic and Svecofennidic orogenies in Finland both have an age of about 1800 m. y. Within the Karelidic belt are mantled domes of basement gneiss, described by Eskola and others. Zircons (isotopic U–Pb), and in one case feldspar (Rb–Sr), from these domes have ages of approximately 2600 m. y., whereas K–Ar and Rb–Sr ages of biotite from the same samples of gneiss are of Karelidic age—*i.e.*, 1800 m. y. This is analogous to the results of measurements on similar

domes of Baltimore gneiss, where zircon (isotopic U–Pb) and feldspar (Rb–Sr) ages of 1000 m. y. record the "Grenville" orogeny, and the biotite ages of 300 m. y. record the Appalachian orogeny.

Farther east in Karelia are larger areas of basement gneiss from which ages of 2600 m. y. have been obtained on zircon, feldspar, and muscovite. The biotite Rb–Sr and K–Ar ages agree at 1800 m. y., which indicates the pervasive effect of the metamorphism at this time.

DIFFERENTIAL THERMAL ANALYSIS AND INFRARED-ABSORPTION SPECTRA OF SOME ZEOLITES AND OTHER HYDROUS SILICATES

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Differential-thermal-analysis curves and infrared-absorption spectra are given for analcime, erionite, heulandite, scolecite, thomsonite, datolite, pectolite, and prehnite.

Of the zeolites studied, only erionite gives a DTA in which water loss is represented by a broad low-temperature endothermic reaction. The DTA curves of the other zeolites studied show one or more sharp but complex low-temperature endothermic reactions. The infrared-absorption spectra of analcime, scolecite, and thomsonite show several O—H stretch bands, which represent different O—H bond distances. In these zeolites, the complexity of the low-temperature reactions in the DTA is attributed to the differences in water bonding as shown by the infrared-absorption spectra. Treating thomsonite with solutions saturated with the calcium or sodium ion did not affect its DTA pattern significantly. The DTA curves of zeolites published by various workers show slight variations, probably because of slight differences in composition of the mineral or DTA procedure, but the curves are characteristic enough to be useful for identification.

DTA patterns of datolite, pectolite, and prehnite are simple and are characterized by strong endothermic reactions at temperatures above 700° C. Datolite and pectolite give complex infrared absorption spectra.

LATE PLEISTOCENE GLACIAL SEQUENCE FOR WEST SIDE OF IZTACCÍHUATL, MÉXICO

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After development and subsequent erosion of the volcanic range Sierra Nevada east of the Mexico basin, including the volcano Iztaccíhuatl at the south end, a series of multiple glaciations alternated with volcanic activity at the north end of Iztaccíhuatl to result in the following sequence: probable mid-Pleistocene glaciation down to 2450 m; volcanism blocking southward drainage from the Valley of Mexico; development of thick yellow podzolic soil on all deposits; late Pleistocene twofold glaciation to 2830–3015 m and outwash as alluvial fans along the mountain front, with moraines, which are now severely eroded, and a strongly developed gray-brown podzolic soil; emission of lava (covered in part by moraines of next glaciation); multiple glaciation with belt of moraines at 3135–3400 m and alluvial fans at mountain edge, with moraines somewhat eroded and a moderately developed soil; emission of lava onto these latest moraines, with later ash and lapilli falls; glaciation building small moraines only in the southwest valleys at 3630–3760 m and outwash only in upper valleys and on fan heads below; black ash fall; weak soil development; construction of small lapilli tuff cone making highest peak of mountain; minor glaciation with huge moraines only in valley-head mouths at 4270–4450 m and mudflow deposits; recent pulsations of little glaciers producing three and four recessional moraines.

EFFECTS OF WEATHERING ON STABILITY OF PALEOZOIC SHALES AND CLAYS

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This study is concerned with structural changes and stability of preconsolidated clays and shales as they are affected by the dynamic physiochemical processes of weathering.

Weathering of fresh exposures of preconsolidated clays and shales takes place in two steps which overlap in time: (1) water absorption, oxidation, and the formation of soluble salts; (2) leaching of soluble salts.

Most preconsolidated clays and shale contain pyrite. During the first stage the pyrite weathers to ferrous sulfate and sulfuric acid, and the sulfuric acid reacts with any lime in the clay material to form gypsum. The water absorption of the clay minerals, the reorientation of the clay minerals caused by soluble salts, and the formation of gypsum all create expansion which must take place in the direction or directions of least resistance. This is the stage when ravelling and spalling occur.

In the second stage, leaching creates instability in the reoriented clay minerals, and soil creep and landslides are common.

SENARMONTITE-VALENTINITE AND ARSENOLITE-CLAUDETITE RELATIONS DETERMINED BY DISPLACIVE SHEARING

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Reconstructive transitions in oxides (especially those involving changes in bond type) in general cannot be studied directly at temperatures below 1000° C. Previous work on the oxides of lead, $ThSiO_4$, TiO_2, and SiO , have demonstrated the effectiveness of "displacive shearing" at high pressures. Application of displacive shear in combination with static pressure has resolved some of the conflict over the nature of the transitions in arsenic and antimony trioxides. Studies were made over the range 0 to 100,000 bars and 0° to 600° C.

Senarmontite (Sb_2O_3-cubic) will convert to Valentinite (orthorhombic) and vice-versa in a straightforward manner either hydrothermally or in uniaxial static-pressure devices. The univariant P-T curve has a slope of -14 atm./deg. and confirms the literature transition temperature at atmospheric pressure of 560° C.

Arsenolite (As_2O_3-cubic) will convert to claudetite (monoclinic) under static pressure in the presence of water readily or will convert in a dry state rather sluggishly. The reverse reaction will not take place under static conditions at any pressure up to 100 kb. If the material is sheared under pressure, the reaction reverses, and nearly 100 per cent conversions of claudetite to arsenolite have been obtained. Thus the reaction is not monotropic as has been stated in the literature. The univariant equilibrium curve has the unusual slope of $+3000$ atm./deg. and intersects the temperature axis at 100° C. These data are inconsistent with presently accepted (though poorly determined) thermodynamic parameters for this transition.

SYSTEMATIC QUANTITATIVE AREAL VARIATION OF SIX GRANITIC MASSIFS

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New analyses yield trend-surface maps for each of several variables in six granites of diverse types and enable evaluation with more precision of the quantitative areal composition and variation. The sampled populations of specimens suggest systematic areal variations. Such trends are probably

a common feature of most granite masses, although some earlier work on New England and other granites might suggest widespread uniformity within many massifs. The present conclusions are based upon areally distributed modal and radioactivity (α activity) data from the Deloro and Wollaston plutons (Ontario), modal data from Mayurbhanj (India), the Beinn an Dubhaich granite (Scotland), and the Donegal "older granite" (Ireland). Most of these data are published. Quantitative areal data are available for very few other granitic bodies.

The Deloro and Wollaston plutons and the "older granite" of Donegal indicate well-defined trends for several modal variates; the trend components are readily correlated with previously published structures of the massifs. Contrary to expectation, statistical correlations between similar variates (*e.g.*, quartz percentage, color index, and feldspar ratio) are not of the same sign for each massif. The Mourne Mountain granite G2 has been described as essentially uniform with no systematic variation, but now some definite trends are demonstrated. For the Mayurbhanj and Beinn an Dubhaich granites trend components indicate that published modal data for the sampled populations are inadequate bases for estimating trends for the target populations (whole massifs), but considerable areal variability is established.

OPTIC-ANGLE DETERMINATION ON THE SPINDLE STAGE

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The optic angle of a crystal mounted on the spindle stage obliquely in respect to the indicatrix may be determined graphically using the Fresnel construction.

Two mutually perpendicular axes of rotation are available: the spindle axis and the microscope axis. At successive settings of rotation about the spindle axis, for example at 10-degree intervals, the corresponding extinction positions are read off the microscope-stage scale. Plotted stereographically, these furnish two curves: the "equatorial" curve crossing the equator, and the "polar" curve passing through the poles of the net. The symmetry axes of the indicatrix are located provisionally by interference figures, then precisely by adjusting their plots slightly if necessary, so that the optic normal and one bisectrix lie directly on the equatorial curve and the other bisectrix lies on the polar curve, all exactly 90° from each other. By a simplified Fresnel construction using different trial values of optic angle, the correct optic angle is determined as that one which satisfies the observed series of extinction positions.

The sensitivity of this method appears to be greater for mounts in which one or both optic axes pass near the microscope axis during rotation around the spindle axis. No corrections to angular rotations are required, and strong birefringence does not particularly handicap the determination. The method thus furnishes an independent value of optic angle, useful in checking the consistency of the three principal indices (determinable on the same grain) or in calculating a third principal index that cannot be reached by the immersion method.

MAJOR WESTWARD THRUSTING OF POST-MIDDLE TRIASSIC AGE IN NORTHWESTERN NEVADA

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Nonmetamorphosed Permian to Middle Triassic rocks consisting of, from bottom to top, 1000 feet of limestone, 400 feet of mudstone, chert, and graywacke, and 600 feet of silty shale have been thrust westward on probable Permian or older metavolcanic rocks at the south end of the Kings River Range.

The upper-plate rocks, particularly the limestone unit, represent facies distinctly different from rocks of the same age in the Jackson Mountains to the south. In the Jackson Mountains all the rocks are metamorphosed but consisted originally of a thick andesite unit, overlain by a thick predominantly clastic sequence consisting of a lower unit of interbedded graywacke, basic volcanic rocks, silty cherty shale, pebble conglomerate, and some silty and sandy limestone, grading into an upper unit of shale with thin chert and carbonate beds.

Permian rocks of the upper plate are similar to Permian rocks exposed in southeastern Humboldt County and thus seem to be a more easterly facies than the rocks in the Jackson Mountains. The absence of metamorphism in the upper-plate rocks and the facies differences require east-to-west transport measured in tens of miles. This substantiates both the direction and amount of displacement postulated by Muller (1949) for some post-Triassic thrusting in the Sonoma Range.

The abundant volcanic material in the Permian rocks of northeastern California and at the locality discovered recently by Gianella and Larson (1960) in the Black Rock Range, Nevada, indicates that the upper-plate rocks have not moved from west to east.

THOMPSON-MOAK LAKE NICKEL BELT

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The Thompson-Moak Lake nickel belt lies along the root of a Precambrian mountain chain of the island-arc or alpine type. The nickeliferous peridotites and nickel ores occur along a negative gravity strip, which also coincides with strong thrust faulting and the axis of greatest deformation of the mountain range. Similar structures and highly nickeliferous peridotites occur in present-day island arcs.

Much of the belt is covered by Paleozoic rocks, but a length of 270 miles may be explored by present-day methods. Nickel deposits have been located along 60 miles of the belt. The length of the favorable structure and the size of the known deposits suggest that this will be one of the world's major nickel regions.

The regional gravity anomalies, which consist of the negative strip bordered by two positive strips, are best explained by major warps of the boundary between granitic and basaltic layers of the crust.

The ore deposits occur in serpentinized peridotite or in gneiss near peridotite. The sulfide mineralogy is similar to that of the Sudbury ores, but the structure of the ore in gneiss is different, and the Manitoba ores are almost entirely nickel. The mineralogy of the silicate gangue in the gneissic ore is typical of the almandine amphibolite facies, sillimanite-almandine subfacies. Possible igneous and metamorphic origins are considered as a guide to further research on the problem of genesis.

REGRESSIONS OF PHYSICAL PROPERTIES ON THE COMPOSITION OF CLINOPYROXENE. II. OPTICAL PROPERTIES AND SPECIFIC GRAVITY

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New regression coefficients of five physical properties (n_x, n_y, n_z, $Z\Lambda c$, and G) on 15 variables of chemical composition in clinopyroxene [ABC_2O_6 = (K, Na, Ca, Mn, Fe″, Mg)(Mn, Fe″, Mg, Ti, Fe‴, Al)$(Fe^{‴}, Al, Si)_2O_6$], calculated by least squares from data in 155 selected published descriptions, yield new "best" estimates of the values of these properties for important compositions; the estimates of refractive index are statistically accurate to ±.005 or better at the 90 per cent confidence level for all principal "end-members" except johannsenite and jadeite, for which data are insufficient or of insufficient accuracy. The standard deviations decrease as the composition approaches the over-all mean composition of the specimens used and reach an optimum of ±.0008 for the refractive indices of the mean.

Best values and standard deviations for some "end-members" are:

	$n_{g'} \perp b$	n_b	n_g	$Z \wedge c$	G
Diopside	1.6658 ± .0013	1.6720 ± .0014	1.6946 ± .0014	39.9 ± .9	3.261 ± .016
Hedenbergite	1.7260 ± .0025	1.7318 ± .0026	1.7551 ± .0027	42.5 ± 1.7	3.538 ± .041
Clinoenstatite	1.6503 ± .0030	1.6484 ± .0031	1.6605 ± .0033	22.4 ± 1.9	3.209 ± .044
Clinoferrosilite	1.7691 ± .0042	1.7677 ± .0043	1.8867 ± .0046	44.1 ± 2.7	3.797 ± .069
Acmite	1.7710 ± .0027	1.8103 ± .0028	1.8271 ± .0030	104.0 ± 2.0	3.584 ± .038
Jadeite	1.6560 ± .0051	1.6647 ± .0053	1.6743 ± .0057	48.5 ± 6.5	3.272 ± .049

The remarkable success of the regressions in predicting optical properties of clinopyroxenes lends support to the hypothesis of linear, additive variation of these properties throughout the entire clinopyroxene system, and thus to the suggestion that the system should be described as a single unit.

HYDROGEOLOGY OF THE MIDDLE BRANCH VALLEY NEAR CANTON, OHIO

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The Middle Branch Valley overlies the course of a buried valley that was cut into the Pottsville formation of Pennsylvanian age before the advance of Illinoian ice over the Canton, Ohio, area. In the lower part of the Pottsville formation are two thick sandstone members, the Sharon conglomerate and the Connoquenessing sandstone, which form the floor and lower walls of the buried valley. The glacial drift that fills the buried valley is coarse sand and gravel outwash of Illinoian and Wisconsin ages.

At the Northeast Well Field, near the southern end of the Middle Branch Valley, the city of Canton pumps an average of about 10 million gallons of ground water per day from the buried valley. The water pumped from the glacial aquifer is replenished by infiltration induced from the Middle Branch of Nimishillen Creek and by diverted ground-water runoff. Siltation of the stream bed limits the amount of infiltration induced from the stream.

Diverted ground-water runoff is the principal source of the water pumped at the well field. It is derived from three sources: (1) precipitation that percolates to the water table within the cone of depression developed around the well field; (2) diversion of part of the natural underflow that moves down the valley through the outwash deposits; and (3) diversion of part of the water that enters the outwash deposits from the sandstone beds that form the floor and lower walls of the buried valley.

STATUS OF GEOCHEMICAL PROSPECTING FOR PETROLEUM IN THE USSR

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Geochemical methods of prospecting for petroleum are receiving more attention in the USSR than in the western world. The Soviets have worked on several different methods for many years and have held periodic meetings in Moscow to analyze their results. The most recent meeting was held April 21–26, 1958, under the auspices of The Academy of Sciences. Two hundred thirty-seven representatives from 68 organizations heard 77 papers on all aspects of this problem.

The Soviets have apparently developed some prospecting methods that have not been investigated in this country. These involve: (1) testing subsurface waters for anomalous concentrations of propane-oxidizing bacteria and dissolved hydrocarbons, and (2) investigating shallow cores for their hydro-

carbon content. Currently geochemical methods are being investigated under various field conditions ranging from the permafrost regions of northern European Russia to the desert wastelands of Turkmenia.

Many claims concerning the effectiveness of geochemical prospecting have been made by the Soviet proponents. Most recently, they report successful applications near Ukhta, Stavropol, and Povolzhe. Despite these claims, no evidence has been found that their methods have been adopted in routine petroleum exploration, apparently for two reasons: (1) not enough evidence has been produced to convince the administrators of petroleum exploration of the reliability of the methods, and (2) strong opposition to geochemical prospecting has developed in certain quarters of their industry. In effect, the Soviets are engaged in an extensive research program to develop techniques that they hope to use in conjunction with conventional prospecting methods.

HYDROGEN AS A COMPONENT IN BIOTITE PHASE EQUILIBRIA

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The equilibrium assemblage biotite-sanidine-magnetite-vapor has been determined as a function of biotite composition (Fe/Fe + Mg), temperature, total pressure, and composition of vapor phase (H_2/H_2O). The reaction:

$$\underset{\text{annite}}{KFe_3AlSi_3O_{10}(OH)_2} + \tfrac{1}{2}O_2 \rightleftharpoons \underset{\text{K-feldspar}}{KAlSi_3O_8} + \underset{\text{magnetite}}{Fe_3O_4} + H_2O \quad (1)$$

may be expressed as:

$$\underset{\text{annite}}{KFe_3AlSi_3O_{10}(OH)_2} \rightleftharpoons \underset{\text{K-feldspar}}{KAlSi_3O_8} + \underset{\text{magnetite}}{Fe_3O_4} + H_2 \quad (2)$$

No variation was found in biotite composition (Fe/Fe + Mg), temperature, and hydrogen fugacity of reaction (2) with a change of total pressure between 1000 bars and 2000 bars, as the volume change of the solids is small (0.2 ± 6.0 cc/mole). The molar volume of annite has been determined as 152.6 ± 2.0 cc/mole, and the partial molar volume of annite in annite-phlogopite solid solution ranges between 152.6 and 153.5 cc/mole. Oxybiotite or anomite ($KFe^{+2}Fe_2^{+3}AlSi_3O_{10}O_2$) apparently forms as a metastable intermediate stage of reaction (2). Hence the oxidation state as well as the stability of a biotite will be influenced by hydrogen fugacity. Low water contents in some biotite analyses may be due to reaction (2) taking place during analysis.

PENNSYLVANIAN AND PERMIAN CODIACEAN ALGAE

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Remains of leaflike calcareous algae belonging to the genera *Anchicodium* Johnson, *Ivanovia* Khvorova, and a new genus occur commonly in Pennsylvanian and early Permian marine carbonate strata. These three genera are considered to be closely related codiacean algae characterized by thalli consisting of calcified blade fragments 0.2 mm–1.2 mm thick and several centimeters in length and width, and a similar, though generically distinguishable, layered internal structure differentiated into cortex and medulla. Bilateral symmetry of the internal structure and other morphologic features suggest that these algae had an erect growth habit. Perforations in the thallus and presumed reproductive organs are found in the new genus but are unknown in *Anchicodium* and *Ivanovia*. These codiacean algae are interpreted as having generally inhabited the inner sublittoral environment at a depth below vigorous wave agitation and are recognized as important world-wide contributors to both biohermal and nonbiohermal carbonate facies.

CRYSTALLOGRAPHY OF MCGOVERNITE AND DIXENITE, TWO COMPLEX ARSENOSILICATES

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Mcgovernite from Franklin, New Jersey, has the largest unit cell yet discovered for an inorganic material which is not a stacking polytype. The mineral has probable space group $R\bar{3}2/c$ and unit-cell dimensions a = 8.22 Å, c = 205.5 Å, as determined from oscillation photographs and confirmed by precession photographs. The primitive unit cell contains 6 $Mn_9Mg_4Zn_2As_2Si_2O_{17}(OH)_{14}$. Dixenite, from Långban, Sweden, has an identical value of a but has a value of c equal to $\frac{3}{11}$ that of mcgovernite. Zero-level c-axis diffraction patterns of the two minerals are indistinguishable. Packing considerations and an observed substructure suggest that the structure may be based on close-packed sheets of oxygen ions with cations in octahedral interstices.

COKING PROPERTIES OF ROCKY MOUNTAIN COALS

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Coal deposits of the Rocky Mountain region contain very large reserves, but only a few of these deposits contain coking coals. The coking coals are mostly high-volatile coals. None of the coals alone produces acceptable coke for blast-furnace feed. The coking characteristics of these coals vary greatly from one deposit to another. The differences in plasticity and swelling properties are marked. Coke produced from these coals also varies in the tumbler and drop-shatter values. Blending coals required to bring the coke to blast-furnace grade vary according to the coking characteristics of the original coal.

Petrographic studies of several coking coals show distinct differences in composition with respect to the concentration of the macerals exinite, vitrinite, fusinite, and semifusinite. Variations in petrographic composition help to explain the different behaviors of the various coals. Exinite increases plasticity but also increases fracturing in the coke. Fusinite is inert and affects the coking properties in proportion to its concentration.

SYSTEM Cu–Fe–S AT 700° C.

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The T-X relations in the system Cu–Fe–S were studied at 700° C. by silica-glass-tube quenching experiments, X-ray diffraction of powdered samples at high temperature, and differential thermal analysis. Chalcocite (Cu_2S), digenite (Cu_9S_5), and bornite (Cu_5FeS_4) are isostructural (cubic) and miscible in all proportions at 700° C. (referred to as bornite solid solution). The cubic polymorph of Cu_2S, however, cannot be quenched to room temperature. Bornite solid solution also includes compositions containing more metal than Cu_5FeS_4 (to 12.2 weight % Fe and 63.4 weight % Cu) and extends toward chalcopyrite solid solution to a composition of 18 weight % Fe, 55.5 weight % Cu. The highly copper-deficient bornite mixcrystals exsolve lamellar chalcopyrite mixcrystals even when rapidly cooled to room temperature. The area of chalcopyrite solid solution extends from 44.0 weight % Cu, 25.8 weight % Fe to 24.5 weight % Cu, 40.5 weight % Fe and does not include the compositions $CuFeS_2$ (stoichiometric chalcopyrite), $CuFe_2S_3$ (cubanite), or $Cu_2Fe_4S_6$ at 700° C. Chalcopyrite mixcrystals are cubic at 700° C., but only the metal-rich compositions can be quenched to room temperature. In addition, copper-rich mixcrystals exsolve lamellar bornite mixcrystals during rapid cooling.

Stable assemblages in equilibrium with vapor are (br = bornite solid solution, cp = chalcopyrite

solid solution, po = pyrrhotite solid solution, py = pyrite, and L = a liquid composed of essentially pure sulfur): br-L, br-cp-L, cp-L, cp-py-L, cp-py-po, py-po, cp-po, br-cp, br-cp-po, br-po, br-po-Fe, br-Cu-Fe, and br-Cu.

MOLECULAR-WEIGHT DISTRIBUTION IN A PETROLEUM ASPHALTENE

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The asphaltene fraction, obtained by n-pentane precipitation from the Upper Tuscaloosa crude oil, Baxterville Field, Mississippi, was fractionated by chromatographing on anhydrous sodium carbonate powder. The chromatographic fractions were obtained by successive elution with cyclohexane, ethyl ether, benzene, chloroform, and ethanol-chloroform (1:1); the nonelutable portion (residue) was recovered by dissolving the sodium carbonate in water and extracting with chloroform. The proportion of the total asphaltenes recovered in the successive fractions, averaged for 25 separate fractionations, was 4.3, 20.4, 24.3, 37.7, 9.1, and 3.6 per cent, respectively.

Attempts to determine the number-average molecular weight of the cyclohexane-eluted fraction by osmotic-pressure methods were unsuccessful because of permeation of the osmotic membrane by solute molecules. Osmotic-pressure determinations on carbon tetrachloride solutions of the remaining fractions at 30° C. yielded the following average molecular-weight values: 23,300; 42,000; 56,300; 73,200; and 76,700, respectively.

Intrinsic-viscosity measurements on carbon tetrachloride solutions of the asphaltene fractions were also determined in order to obtain the values for the constants, a and k, in the Mark-Houwink equation $(\eta) = kM^a$. Since a log-log plot of (η) vs. M showed linearity in the lower molecular-weight region (23,000–56,300) only, the calculated constants, $a = 0.18$ and $k = 3.8 \times 10^{-7}$, have restricted application to this lower range. The values of these constants are substantially below the range determined, from theoretical and empirical studies, for varying molecular-weight fractions of synthetic polymer systems. This evidence and the variations shown in the elemental analyses of the asphaltene fractions suggest that petroleum asphaltenes are not simple polymeric systems.

BASAL SEDIMENTARY SECTION AT WINDY GULLY, TAYLOR GLACIER, VICTORIA LAND, ANTARCTICA

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The contact between the basement complex and the sedimentary sequence in the Royal Society Range, Antarctica, is well exposed on both sides of Windy Gully along the main valley of the Taylor Glacier. The section rests on a granitoid crystalline basement complex. Dark, coarse-grained gneissic rocks are exposed at several points along the basement-sedimentary contact. The basal sedimentary beds consist of cross-bedded sandstones, which include large cobbles and boulders of weathered crystalline rocks. Relief on the basement surface is 80–100 feet locally and probably much greater in the surrounding area.

Overlying the basal sandstone is a sequence of 110 feet of alternating sandstones and dark fissile shale. Overlying these beds are massive sandstones of the normal Beacon lithology. Approximately 255 feet above the base of the Beacon lies a massive diabase sill 960 feet thick. The Beacon section was measured for 390 feet above the top of the sill. It seems to continue above this for several thousand feet, interrupted only by thick diabase sills. The upper part of the measured section probably overlaps with the lower portion of the Beacon section recently described by McKelvey and Webb (1959) which they called Member A.

TIME AND SPACE RELATIONSHIPS OF THE TACONIC ROCKS IN WESTERN VERMONT AND EASTERN NEW YORK

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Workers at the north end of the Taconic area traditionally hold that rocks of the Taconic facies, dominantly shale and graywacke, are allochthonous, whereas workers at the south end believe them to be autochthonous. Both views may be locally correct but must be reconciled.

An allochthone is demonstrable at the north end of the Taconic area. The rocks probably were deposited at the present site of the Green Mountains; they constitute transitional types between the eugeosynclinal (east) and miogeosynclinal (west) facies. A Middle Ordovician (Normanskill) unconformity in the allochthone probably correlates with a pre-Lowville unconformity in the adjacent autochthone, beneath the Whipple marble (Fowler, 1950) that marks an abrupt and enduring shift from carbonate to shale-graywacke deposition. At the junction between the allochthone and autochthone are (1) Wildflysch-type conglomerate in autochthonous slate, and (2) wedges of upper Beekmantown autochthonous-type carbonate rocks. Available evidence suggests westward overlap of clastic sediments and also the inception, to the east, of Taconic thrusting during Normanskill time. Thrusting lasted into late Normanskill (Trenton) time.

Within the southern Taconic area, Normanskill and higher rocks are demonstrably autochthonous; they rest in normal succession on the Whipple-correlative Balmville limestone member of the Wappinger limestone (Holzwasser, 1926). This relationship reflects the same westward overlap of the Taconic facies, which during Trenton time is thrust over by rocks of the same age and lithofacies Evidence or need for separate sedimentary basins for each facies is lacking. The Taconic allochthone. may be areally much less extensive than hitherto shown.

GEOCHEMICAL ASSOCIATIONS OF CERTAIN MINOR ELEMENTS IN COAL

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The analytical data for 15 minor elements in the ash of float and sink fractions of coal show that they are associated with the organic matter of coal in the following order: Ge, Ga, V, Be, Ti, B, Ni, Cr, Co, Y, Mo, Sn, Zn, La. Three pairs of these elements show an interesting relation which may be indicative of their method of association with the coal. These are V and Cr, Ni and Co, and Y and La; V, Ni, and Y have a higher degree of association with the organic matter than do their counterparts, Cr, Co, and La. The stability constants of a large number of chelates of the first group are higher than those of their counterparts. This suggests that a large part of these elements are retained in coal as metallo-organic complexes.

Another indication that complex formation is a principal means by which these elements are retained in coal is that there is a higher degree of association with the organic matter of coal for elements of the first transition series and those immediately adjacent to the series, which generally form more stable organic complexes than elements outside the group.

The distribution of some of the elements within the bed of coal suggests two methods of control: (1) by changing availability of the elements, and (2) by changing Eh and its resulting influence on metallo-organic complex formation. Where unusual concentrations of any of these elements are found, they may be held in the coal by ion exchange or as components of minerals.

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* Deceased

ABSTRACTS OF PAPERS SUBMITTED FOR THE MEETING IN LEXINGTON, KENTUCKY, MARCH 24, 25, AND 26, 1960

METAMORPHIC-ROCK ASSOCIATIONS OF GREENE AND MADISON COUNTIES, VIRGINIA*

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The Greene County-Madison County area in north-central Virginia includes about 480 square miles within a part of the Blue Ridge and upper Piedmont physiographic provinces. The three major groups of rocks represented in the area are, from oldest to youngest: (1) a Precambrian igneous and meta-igneous complex of granitoid, gneissic, and migmatitic rocks; (2) a metasedimentary complex including metavolcanic rocks; and (3) flows and pyroclastic rocks commonly known as Catoctin greenstone. The igneous and meta-igneous complex constitutes the core of the northeasterly trending Blue Ridge anticlinorium and contains infolded metasedimentary and metavolcanic material known as the Mechum River metasediments. Three general facies are recognized in the igneous and meta-igneous complex, with gradational boundaries between: an older biotite granite gneiss facies, a granodiorite facies, and a younger hornblende granite facies. Dike- and sill-like bodies of amphibolite are found within the igneous and meta-igneous complex and metasediments, and aplitic and pegmatitic dikes cut the igneous facies. Metasomatism and migmatization are evident within the igneous and meta-igneous complex and are strongly evident adjacent to the infolded Mechum River metasediments and to the bordering metasediments (Lynchburg) to the southeast.

A pervasive, southeast-dipping, slaty cleavage characterizes the metasedimentary units. Northeast-trending zones of intense shearing pass through the meta-igneous rocks and metasediments and are particularly well developed at and near meta-igneous and metasedimentary contacts. The large-scale shearing activity appears to be contemporaneous with metasomatism.

STATISTICAL STUDY OF NEAR-SURFACE SEISMIC-VELOCITY DETERMINATIONS IN INDIANA†

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The Indiana Geological Survey has made more than 4000 seismic-refraction measurements for the determination of thickness of unconsolidated material throughout Indiana. This work was done to provide data for research in glacial geology, for foundation investigations, and for coal-reserves studies. More than 9000 longitudinal wave velocities of bedrock and unconsolidated sediments resulted from depth computations for this work.

A statistical study of these velocities has shown peaks of velocity distributions at 1200, 6300, 10,500, and 15,600 feet per second. These correspond respectively to dry, aerated material; water-saturated, unlithified sediments; shale and sandstone; and limestone. Although distinct, the shale and limestone distributional peaks have a 50 per cent overlap for velocities within the range 8000 to 15,000 feet per second.

Velocities of rocks of different ages but of the same lithology are essentially the same for all stratigraphic units studied. Devonian, Mississippian, and Pennsylvanian shales range in velocity from 7000 to 13,000 feet per second and have a mean velocity of 10,500 feet per second. Devonian and Silurian limestones differ in their mean velocities by 1200 feet per second but have the same ranges—13,000 to 22,000 feet per second.

The New Albany shale (mean velocity 10,700 feet per second) and the stratigraphically adjacent Devonian limestone (mean velocity 16,500 feet per second) show a strong velocity contrast and little velocity distributional overlap. Preliminary field work indicates that with certain limitations the contact between these units may be mapped by seismic-refraction methods.

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* Publication authorized by the Virginia Division of Mineral Resources

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USE OF VELOCITY LOG DATA TO CONFIRM SEISMIC VELOCITIES AND REFLECTIONS TO THE BASEMENT COMPLEX IN INDIANA*

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Data from a continuous velocity log of the Indiana Farm Bureau No. 1 Luther Brown test well in Lawrence County, Indiana (SE¼SE¼ sec. 20, T. 5 N., R. 2 E.), gave the following average vertical velocities from a datum in the New Albany shale 132 feet above sea level: to the Trenton limestone 13,500 feet per second, to the Knox dolomite 14,900 feet per second, to the Mt. Simon sandstone 16,500 feet per second, and to the basement complex 16,250 feet per second.

An analog computer was used by the Indiana Geological Survey in conjunction with seismic equipment to simulate a seismic pulse and its resulting seismogram. This seismic record and the data from the continuous velocity log were used to compute a synthetic seismogram on an I.B.M. 650 computer at the Indiana University Research Computing Center. Comparison of the synthetic seismogram with a field seismogram made 0.6 mile east of the logged well showed correlations for markers identified as the Trenton limestone, upper and lower parts of the Knox dolomite, the Eau Claire formation, the Mt. Simon sandstone, and the basement complex. Although the continuous velocity log did not show a large velocity contrast in the vicinity of the basement complex, the synthetic seismogram demonstrated that energies reflected from this transition zone combined to give a recognizable signal.

FAULTING AT BROCK'S GAP, ROCKINGHAM COUNTY, VIRGINIA, AND POSSIBLE EFFECTS ON LITTLE NORTH MOUNTAIN†

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The north wall of Brock's Gap, a water gap of the North Fork of the Shenandoah River in Little North Mountain, shows two northwest-dipping faults inclined between 25° and 40° and converging toward the northwest. The drag indicates that both faults are reverse faults. They are at the east end of the gap and at, or near, the boundary between the Oswego sandstone to the west and the Martinsburg shale to the east.

Some of the changes in thickness of the Oswego sandstone on the southeast side of Little North Mountain in Rockingham County could be accounted for by a northwest-dipping reverse fault with varying stratigraphic displacement. Reconnaissance several miles to the northeast in Shenandoah County indicates that such a fault might help to explain several of the stratigraphic irregularities in Little North Mountain.

NEWLY DISCOVERED SILLIMANITE DEPOSIT IN PICKENS COUNTY, SOUTH CAROLINA‡

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A sillimanite deposit in a linear roof pendant consisting of folded metasedimentary rocks within biotite granite gneiss has recently been discovered. The metasediments consist of hornblende gneiss, mica schists, and mica gneisses, which are intruded by pegmatites. Sillimanite is most common as disseminated acicular crystals in muscovite schist but is also found in biotite schists and the pegmatitic rocks. The occurrence is similar to the other sillimanite deposits in South Carolina, North Caro-

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‡ This study was conducted under the auspices of the Division of Geology of the South Carolina State Development Board.

lina, and Georgia but differs from most of them in the occurrence of pods of coarsely crystalline sillimanite boulders up to 3 feet in diameter. Such cobble- or boulder-sized masses are found as residual float. One 6-inch pod was found within a nest of small slender black tourmaline crystals.

Garnets are common in the schists and gneisses and are present in some pegmatitic material. Graphite flakes are less common but are conspicuous in some schists and are present in small quantities in some of the pegmatite materials and sillimanite pods. The foliation of the rocks is generally N. 60° E. with a dip of 20°–60° varying from northwest to southeast. The topography is structurally controlled; the low linear ridges trend northeast and are underlain by the sillimanite-bearing rocks. Lower knobs are generally underlain by the inequigranular biotite granite gneiss.

Petrographic studies are made of the various units. Because of the lack of outcrops, studies were made of soil samples to determine the continuity of the sillimanite-bearing rocks in much of the area.

OCCURRENCE OF LITHIUM, BORON, BROMINE, FLUORINE, AND IODINE IN NATURAL GROUND WATERS OF THE COASTAL PLAIN OF NORTH CAROLINA

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Ground waters from sedimentary rocks in the Coastal Plain of North Carolina reflect the chemical nature of the host rock. However, owing to processes of disintegration and decomposition, the differences in chemical composition of the original rock units are not sharp. The ground-water samples from these rocks exhibit gross chemical characteristics that are more closely related to changes that have occurred while the water has been in storage in the zone of saturation than to the chemical composition of the host rock. The writers believe that some minor elements in natural ground waters are among the best indicators of the chemical nature of the host rock.

The minor elements in natural ground waters can be used to trace ground-water flow, to define geohydrologic environments, and to indicate the presence of mineral deposits of potential economic value. Concentrations of lithium, boron, bromine, fluorine, and iodine have been determined in waters emanating from rocks of Cretaceous, Paleocene, Eocene, and Miocene age in the Coastal Plain. Four anomalous concentrations of one or more of these constituents are interpreted as indicating unusual geohydrologic environments, two of which may have potential economic value.

WISCONSIN MOLLUSCAN FAUNAS FROM JEFFERSON COUNTY, KENTUCKY

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The area south of Louisville in Jefferson County, designated the Valley Station quadrangle, was the site of deposition of Pleistocene sediments—a part of the larger area of Pleistocene sedimentation throughout much of the Ohio River valley. A reconstruction of the history of these sediments is possible using four localities, each of which exposes a part of the sediments. The sediments comprise what appears to be a till of Illinoian age or older, overlain by the Loveland loess of Illinoian age on which the Sangamon soil is well developed; and two deposits of Wisconsin age, the Farmdale loess and the fossiliferous sediments of the Tazewell substage. The Tazewell sediments are loess deposits at two localities, water-laid silts and sands at another, and a complex deposit of loess and water-laid sediments at a fourth.

Eight families, 18 genera, and 25 species of land snails were recovered exclusively from the Tazewell zone (both loess and water-laid sediments) at the four localities. This Pleistocene molluscan fauna is the first recorded from Jefferson County, Kentucky. Nine species representing five families are reported living in the area. Deductions based on the ecological requirements of the fauna presuppose the following conditions: (1) a prevailingly cooler climate where lower annual mean temperatures obtained, since six species are now restricted to northern and mountainous areas; (2) the proximity of permanent lakes or streams; and (3) a more dense floral cover than now exists, since the true forest genera *Anguispira* and *Triodopsis* are present.

INSOLUBLE RESIDUE AS A CORRELATION TOOL IN THE ORDOVICIAN CYNTHIANA FORMATION

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A detailed study of insoluble residues from a horizon of the Cynthiana formation, a sequence of alternating shales and limestones, was undertaken to test the feasibility of correlation. High lateral variability of all aspects of both heavy and light fractions and overlap of zones within the vertical range of the insolubles make detailed correlations impossible. Correlation can be made only when a new heavy-mineral suite or a new species appears.

Size, good sorting, maturity, and limited heavy-mineral content of the rock indicate deposition in a shallow sea quite distant from the source area, a regionally metamorphosed terrane of fairly high rank. Zircon, calcium garnet, amphiboles, and pyroxenes are the principal species in the heavy fraction. Abraded and fragmental zircons have a wide range of sizes, whereas the euhedral zircons are restricted to the silt sizes and are believed to be derived from the erosion of bentonites in or near the source area.

PETROLOGY OF LOWER PENNSYLVANIAN SEWANEE SANDSTONE, LOOKOUT MOUNTAIN, ALABAMA AND GEORGIA

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A petrologic study of texture, including apposition fabric or preferred sand-grain orientation, and mineralogical composition was made in order to deduce petrogenesis. Field studies of stratigraphic and primary structural characteristics supplemented these investigations. Results indicate that the Sewanee, a quartzose sandstone, was formed under tectonically rather stable conditions in transitional depositional environments. Its sediments were mainly derived from the east in regions of the present Piedmont by a south-southwesterly regional sediment-transport system. The source rocks were mainly igneous plutonic rocks with metamorphic rocks of secondary importance; pre-existing sediments were only minor contributors. No textural indication of deep burial is found, and diagenetic changes are confined to some welding and suturing of adjacent quartz grains and the development of sericitic intergrowths of grains and matrix.

A method for sampling and measuring the preferred orientation of sand grains is described. The statistical study of the variability of the mineral constituents of the Sewanee sandstone, both locally and regionally, shows that the rock body is extremely homogeneous. The mean directions of both preferred grain orientation and cross-bedding are, regionally, fairly consistent and coincident with each other. The variations in the analysis of apposition fabric, however, are rather greater locally than regionally. This is related to the environment of deposition.

ARENACEOUS FORAMINIFERA IN THE SILURIAN AND DEVONIAN OF KENTUCKY

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Present investigation demonstrates the fairly wide occurrence of arenaceous Foraminifera in the Silurian and Devonian sequence on all three sides of the Cincinnati arch in Kentucky.

In Kentucky, Foraminifera have been reported from only one Silurian formation, the Osgood shale (Dunn, 1942); these forms were not described or figured. In the Devonian of Kentucky only one genus, *Rhabdammina*?, has been reported, but not described; this form is from the Beechwood limestone of Jefferson County (Conkin, 1958).

Herein seven genera of Foraminifera (*Hyperammina, Involutina, Lituotuba, Proteonina, Psammo-*

sphaera, Thurammina, and *Thuramminoides*) are reported from the Silurian formations: the Waldron shale, Osgood shale, and Estill shale. Eight genera (*Glomospira, Hyperammina, Involutina, Proteonina, Rhabdammina, Thurammina, Thuramminoides,* and *Tolypammina*) are here reported from the Devonian formations: the New Albany shale, Portwood formation, Boyle limestone, Beechwood limestone, Bone bed of Sellersburg age, and the Silver Creek member of the Sellersburg.

Of primary importance is the recognition of *Thuramminoides sphaeroidalis* Plummer, 1945, in the Silurian and Devonian of Kentucky. The heretofore known stratigraphic occurrence of *Thuramminoides* was in the Pennsylvanian of Texas (Plummer, 1945), the Permian of Australia (Crespin, 1958), and the Mississippian of Kentucky, Indiana, and Ohio (Conkin, 1957).

The authors are convinced that *Thuramminoides* has been recorded from rocks of Devonian age under other generic names, including *Thurammina.*

Our studies in Kentucky lead us to believe that arenaceous Foraminifera will be of stratigraphic usefulness within the Lower Paleozoic sequence of North America when sufficient faunas have been described.

INTERTONGUING AND LATERAL GRADATION BETWEEN THE PENNINGTON AND LEE FORMATIONS IN THE TRI-STATE AREA OF KENTUCKY, TENNESSEE, AND VIRGINIA

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The upper part of the Pennington formation and the lower part of the Lee formation intertongue in their type area of outcrop, Lee County, Virginia, and in adjacent areas of Kentucky and Tennessee. The contact between these formations, which has been interpreted as an unconformity between the Mississippian and Pennsylvanian systems, is transitional as the result of intertonguing and lateral gradation between marine and nonmarine facies. Lateral gradation is most evident in sandstone beds, which in the Lee formation are characteristically thickly cross-bedded, fine- to coarse-grained, quartzose, conglomeratic sandstones as much as 300 feet thick. These sandstone tongues of the Lee formation grade laterally to thin wavy-bedded, very fine- to fine-grained sandstones, 20 to 30 feet thick that are typical of, and are included in, the Pennington formation. Conversely, tongues of light-olive-gray, slightly calcareous shale in the upper part of the Pennington formation wedge out between the sandstone tongues of the Lee formation. The Pennington–Lee contact, as determined lithologically in the field, rises stratigraphically northward in this intertonguing sequence.

According to the literature, marine invertebrate fossils indicate the Late Mississippian age of the Pennington formation. In contrast, plant fossils have been reported to show that the Lee formation is of Early Pennsylvanian age. Intertonguing of the Pennington and Lee formations suggests that these formations are partly contemporaneous.

HEAVY-MINERAL OCCURRENCES ON ISLANDS OF THE MISSISSIPPI SOUND AND ADJACENT AREAS OF THE MAINLAND

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Samples of heavy minerals have been collected for 3 years at localities from the Alabama–Florida State line on the east to Cat Island, Mississippi, on the west.

The marked similarity of mineral suites from each of the sampling stations indicates a common source. However, changes in the degree of concentration at each of the locales manifest reworking of the near-shore and bottom sediments. The primary control of this present depositional cycle is being exercised by littoral drift. This is further evidenced by the southwestward migration of the island masses.

Petrographic examination shows that the most frequent minerals of the heavy fraction, following

bromoform separation, include ilmenite, kyanite, rutile, staurolite, tourmaline, and zircon with minor amounts of hornblende and monazite.

WALDRON (NIAGARAN) FORAMINIFERA IN INDIANA

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Recent studies of lower Paleczoic strata in Indiana have revealed significant foraminiferal assemblages in the Richmond group (Ordovician), from which Foraminifera have not been reported previously, and the Waldron shale (Niagaran) from which only one undisputed foraminifer has been described hitherto. The Waldron foraminiferal fauna is particularly notable for its richness in numbers of individuals and diversity of species. Thirty-seven Waldron species are assigned to the following genera, arranged in order of decreasing abundance of specimens: *Sorosphaera, Psammosphaera, Rhabdammina, Thurammina, Webbinella, Hyperammina, Raibosammina, Thekammina, Marsipella, Lagenammina, Stegnammina, Amphitremoidea, Saccammina, Colonammina, Aschemonella, Tholosina, Psammophax,* and *Bathysiphon. Involutina* and *Lituotuba,* both of which are important elements in the Brassfield and Osgood faunas of Indiana, are conspicuously absent.

The discovery of specimens representing growth series in six multichambered species is of great taxonomic importance. Ontogeny from single-chambered to multichambered stages can be demonstrated for three species of *Sorosphaera,* and one species each of *Webbinella, Thurammina,* and a new genus related to *Sorosphaera.* Failure to recognize ontogenetic series can result in useless proliferation of taxa if specimens differing only in number of chambers are assigned to separate species. From detailed study of two small bioherms at Vernon, Indiana, the writer concludes that foraminiferal distribution was controlled closely by local environment; some lithologic units within the bioherms contain abundant specimens, whereas adjacent units are virtually barren. Meaningful evaluation of early Paleozoic foraminiferal populations demands study of large numbers of individuals from each fossiliferous facies at any locality.

AUXILIARY FAULTING ASSOCIATED WITH THE PINE MOUNTAIN THRUST FAULT

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Most of the earlier published material dealing with the Cumberland overthrust block depicted the Pine Mountain fault as a single uncomplicated fault bounding the western limit of the overthrust block. More recently detailed field mapping in several localities along the thrust front has shown that the thrust at its western margin is a complex fault zone with several slices of highly distorted rock dragged up along the zone.

This report describes the structural features of the central portion of the overthrust block near its western extremity. Along this portion of the thrust front one or two auxiliary slices can generally be mapped. A transverse fault zone (Rocky Face fault) has been mapped in some detail, and this also is shown to be not a single tear fault, as reported in the early literature, but rather an en echelon fault zone.

LATE EOCENE FORAMINIFERA FROM SOUTH CAROLINA AND GEORGIA*

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A recent study of the larger Foraminifera in cuttings from wells drilled into the Ocala limestone in Beaufort County, South Carolina, and Chatham County, Georgia, shows that the Ocala contains

* This study was carried on at Cornell University under the direction of Professor W. Storrs Cole.

many of the species previously reported from equivalent strata in Florida and the Caribbean region. In three wells drilled on islands off the coast of South Carolina and Georgia, the upper part of the Ocala consists of 115 feet of flat-white much calcitized somewhat crystalline abundantly fossiliferous limestone. This part of the formation apparentiy represents a typical bryozoan facies, since it is composed predominantly (approximately 98 per cent) of bryozoan remains; the remainder consists of molluscan shells, echinoid spines, and Foraminifera. The larger Foraminifera in this part of the section were *Operculina mariannensis* Vaughan and *Asterocyclina nassauensis* Cole.

Below the upper white limestone zone the Ocala is composed of approximately 255 feet of cream-colored relatively soft and porous but somewhat calcitized granular fossiliferous limestone that contains abundant larger Foraminifera at scattered levels. The species identified from this part of the formation include *Camerina striatoreticulata* (L. Rutten), *Operculina mariannensis* Vaughan, *Lepidocyclina* (*Pliolepidina*) *montgomeriensis* Cole, *Helicolepidina spiralis* Tobler, and *Pseudophragmina* (*Proporocyclina*) *flintensis* (Cushman). This is the first reported occurrence of *Helicolepidina spiralis* in Georgia.

In a well in Turner County, Georgia, the Ocala consists of cream-colored soft granular fossiliferous limestone that carries Foraminifera at scattered, well-separated levels. At or near the top of the Ocala limestone *Lepidocyclina* (*Nephrolepidina*) *chaperi* Lemoine and R. Douville was observed in considerable abundance, and below this zone *Lepidocyclina* (*Pliolepidina*) *ocalana* Cushman was common. The writer plans to continue this study to obtain more data concerning the distribution of the larger Foraminifera in the Ocala limestone of Georgia.

GEOLOGY OF THE GOOSE CREEK FAULTS IN CASEY AND RUSSELL COUNTIES, KENTUCKY

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The writer discovered this isolated but important disturbance of central southern Kentucky at a point 10 miles southwest of Liberty in Casey County in September 1924. The well-defined normal faults occur here with a broad graben separating them. The stratigraphic section consists of 500 feet of sedimentary rocks ranging from Richmond (Upper Ordovician) into St. Louis (Middle Mississippian). The area covered by this disturbance is about 12 square miles. The Cincinnati arch is involved. Domal uplift of a part of this area antedated faulting.

The west or major fault strikes N. 1° W. and is about 12 miles long. Its maximum observed displacement is 350 feet. Drag zone ranges from 100 to 300 feet. Downthrow on the east has dropped the Warsaw limestone (Middle Mississippian) to the level of the Onondaga (Middle Devonian) on the west. The east or minor fault exhibits on the north a strike nearly parallel to the west fault, but on the south it flares to the east. Maximum displacement is about 125 feet; downthrow on the west brings the Warsaw (Middle Mississippian) to a position opposite the middle Fort Payne (Lower Mississippian). The width of the graben ranges from 2000 feet on the north to 5500 feet on the south. The area has been drilled extensively for oil.

BASEMENT MAGNETIC AND GRAVITY ANOMALIES IN SOUTHEASTERN KENTUCKY

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Several aeromagnetic traverses were completed by the U. S. Geological Survey in 1953 across the Appalachian Mountains system; nine of them cover a strip 20 miles wide extending from Louisville, Kentucky, to Kings Mountain, North Carolina. The largest anomalies recorded occur in a clearly defined area 90 miles long between Stanford, Kentucky, and Middlesboro, Kentucky. Depths to magnetic basement rock, estimated from the anomalies, range from 7500 to 11,500 feet. The belt of magnetic basement rocks lies east of the Cincinnati arch. Individual anomalies are discontinuous, and the few trends that appear continuous do not coincide with surface structures. Two of the com-

plex magnetic anomalies lie on the east and west flanks of a positive gravity anomaly that extends from Richmond, Kentucky, to Crossville, Tennessee.

Comparison of the eastern Kentucky high-amplitude anomalies with anomalies near Charlotte, North Carolina, attributed to large exposed masses of diorite and gabbro suggests that the eastern Kentucky basement is (1) part of an unusually large mafic complex, and (2) may contain large masses of rock with a higher magnetic susceptibility than gabbro, such as ultramafic plutonic rocks, Keweenawan-type lava flows, or Precambrian metasedimentary rocks. A segmented positive gravity trend that extends from the Lake Superior region into south-central Kentucky and adjacent Tennessee lends some support to the last two possibilities.

VEGETATIONAL STUDIES OF INTERGLACIAL (SANGAMONIAN) SOILS AND INTERSTADIAL DEPOSITS IN SOUTHEASTERN INDIANA

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Pollen analysis of a buried interglacial soil of Sangamonian age has yielded pollen profiles which establish the vegetational and climatic sequence of the area. Although pollen is not always well preserved in soils, two of the interglacial humic units sampled contain abundant pollen. Extensive stratigraphic investigations at many field localities, and carbon-14 dates have established the chronological sequence of Pleistocene events in the area. The pollen profiles show a vegetational succession during Sangamonian time from conifers, mostly pine, to hardwoods, with a final reversion to a coniferous boreal forest of spruce, fir, and pine. The hardwood period was apparently warmer and drier than the postglacial hypsithermal interval in the region. Spruce wood and mosses were found at the upper surface of the Sangamonian soil, buried by rock flour and the basal Wisconsinan till; these provide a partial record of the flora at the end of the Sangamonian interglacial age. Pollen and moss from Illinoian and Wisconsin interstadial calcareous humic zones indicate that these intervals were probably short and cool.

Attempts to confirm geologic correlations of buried soils and humic zones in this area by pollen analysis have been partially successful, although low pollen frequencies have made this technique impractical in several instances.

PREVIOUSLY UNRECOGNIZED DEVONIAN ROCKS AND A MAJOR FAULT BETWEEN THE SCHUYLKILL AND THE SUSQUEHANNA RIVER, PENNSYLVANIA

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Geologic mapping has revealed that, contrary to previously published reports and maps, there are two outcrop belts of the Oriskany, Onondaga, and Marcellus formations of Early and Middle Devonian age between the Schuylkill and the Susquehanna River. The area mapped is bounded on the north by Second Mountain and on the south by Blue Mountain.

In these belts the Oriskany formation, 0–20 feet thick, is a milky-white to yellow-brown, medium- to coarse-grained, locally conglomeratic quartzitic sandstone. It disconformably overlaps the Bloomsburg red beds of Silurian age from east to west. The overlying Onondaga formation, 0–15 feet thick, is a finely crystalline, dark-gray, fossiliferous limestone and limy shale that may be absent between Indiantown Gap and the Susquehanna River. The Marcellus, 60–150 feet thick, is a fissile dark-gray to black carbonaceous shale that rests on and overlaps the Onondaga from east to west. The Marcellus is overlain by the Montebello sandstone member (Willard, 1937) of the Mahantango formation (Willard, 1935), a buff to light gray-brown, coarse, locally conglomeratic, quartzitic sandstone about 800 feet thick at the Susquehanna River and about 20 feet thick at the Schuylkill.

The two belts of outcrops of these Lower and Middle Devonian rocks lie along the limbs of an

overturned anticline and a shallow syncline to the south. A large thrust fault truncates the north limb of the anticline and, locally, the northern outcrop belt of the Oriskany, Onondaga, and Marcellus formation.

HYDROLOGY OF A QUARRY-DEWATERING PROBLEM NEAR NEW BERN, NORTH CAROLINA

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The U. S. Geological Survey, in co-operation with the North Carolina Department of Water Resources, recently conducted a study of the dewatering of a quarry at New Bern, North Carolina, in order to obtain a better understanding of the hydrology of the limestone and sand units in the area.

The area is underlain by the Castle Hayne limestone of Eocene age. At the quarry the upper part of the formation consists of 30–45 feet of consolidated shell limestone underlain by clean sand. The limestone unit contains water in solution channels and cavities under water table to semiartesian conditions. The two units are connected hydraulically by the solution channels and cavities in the limestone. Withdrawal of water from the sand unit causes partial dewatering of the overlying limestone unit.

In order to maintain a dry quarry, approximately 15,000 gpm are pumped from dewatering wells and pit pumps.

Three possible sources of recharge to the dewatering wells were considered—vertical recharge, lateral recharge, and induced surface recharge from a nearby swamp or from a nearby river. Piezometric maps were drawn using water-level data from observation wells that surround the quarry. Recovery tests were conducted using the observation and dewatering wells. Water samples were collected for chemical analysis from observation wells, dewatering wells, and solution channels. Interpretation of the data obtained indicates that a major portion of the recharge to the dewatering wells is from the nearby swamp.

SOME EFFECTS OF WASTE OIL-FIELD BRINES ON THE STREAMS, WELLS, AND SPRINGS OF THE UPPER GREEN RIVER BASIN, KENTUCKY

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Daily sampling of the Green River at Munfordville, Kentucky, from October 1950 through September 1959 provided a continuous record on which to measure the effect of waste brines from the Greensburg oil field. Before August 1958, the Green River water was of the calcium-magnesium-bicarbonate type and had an average chloride concentration of less than 10 ppm. With the rapid development of the Greensburg oil field in the spring of 1958, the water changed to a sodium-chloride type and had daily chloride concentrations frequently greater than 1000 ppm. Hardness also increased greatly so that domestic and industrial use of the Green River has been affected. While oil production has declined steadily, waste-brine production has remained high. The Green River at Munfordville discharged 305,000 tons of chloride in the 1959 water year compared to 10,600 tons in 1957.

Brines discharged from oil wells in the Greensburg oil field have contaminated the water supplies from a number of wells and springs in the upper Green River basin. Ground-water contamination is concentrated in the areas of heavy brine production in Green and Taylor counties but is noticeable as far away as Brownsville, about 100 miles downstream from the area of greatest oil production. The two large springs known as Echo River and Styx River at Mammoth Cave, about 20 miles upstream from Brownsville, have also been contaminated.

LITHOLOGY AND SOURCE OF THE TUSCALOOSA FORMATION IN WESTERN TENNESSEE

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Typically, the Tuscaloosa formation in western Tennessee consists of well-rounded, poorly sorted chert gravel. Basal beds include angular fragments of chert and iron-stained clay derived from the underlying residuum. Along its eastern limit the Tuscaloosa formation contains local beds of sorted sand and silt.

Typical Tuscaloosa sediment is trimodal in size distribution. The gravel fraction (mode 15 to 40+ mm) consists of about 75 per cent Devonian chert derived from rocks cropping out as far as 50 miles to the west, 20 per cent Mississippian chert of local origin, and up to 5 per cent sandstone pebbles probably derived from Cambrian or Ordovician formations in extreme western Tennessee. The medium-sand fraction (mode 0.5 mm) consists mainly of angular to well-rounded chert grains developed by attrition during transport. Well-rounded and frosted quartz grains also are present and probably were derived from Cambrian or Ordovician bedrock sources. The finest fraction (mode 0.15 mm) consists of clay aggregates, authigenic (?) mica, and quartz.

At its eastern limit the Tuscaloosa is locally well sorted and contains quartz pebbles and an unusually large proportion of quartz sand. Both the quartz pebbles and sand may have been derived from Pennsylvanian bedrock. Also present in the same area are well-sorted heavy-mineral-bearing sands and bimodal (0.04 and 0.2 mm) siltstones which contain sand-size aggregates.

The fine fraction (less than 0.044 mm) of all the lithologic types of the Tuscaloosa consists of 60 to 80 per cent quartz, 5 to 30 per cent kaolin, and 5 to 30 per cent montmorillonite, all of which are present in about the same proportion in weathered Devonian and Mississippian bedrock. Minor exotic constituents include volcanic (?) glass and heavy minerals.

RELATION OF BUCATUNNA CLAY MEMBER OF BYRAM FORMATION TO GEOLOGY AND GROUND WATER OF WESTERNMOST FLORIDA

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Correlation by electric logs, lithology, and fossils indicates that the Bucatunna clay member of the Byran formation (middle Oligocene) extends eastward from its type locality in Mississippi across Alabama into westernmost Florida. Dipping gently southwestward, the Bucatunna underlies all of Escambia and Santa Rosa counties, Florida, and extends eastward across southern Okaloosa County. Wells within this area indicate thicknesses of the Bucatunna ranging from 28 feet near Destin to 215 feet near Pensacola. The Bucatunna rests unconformably upon limestone of late Eocene age and is overlain by limestone of late Oligocene age. The upper contact, at least updip, also is unconformable, as indicated by what appears to be a fossil stream channel cut into the clay.

In westernmost Florida the Bucatunna is a gray silty to sandy illitic clay containing Foraminifera, ostracods, mollusks, and other organisms of middle Oligocene age. The Bucatunna clay member is an almost ideal aquiclude below which ground water is under artesian pressure. In places the clay prevents the salt water below from rising and contaminating the fresh water above. In the northern half of westernmost Florida, the Bucatunna is underlain by several hundred feet of fresh water which as yet is virtually untapped by wells. Rapid industrialization of the area suggests that this large supply of fresh water may become important in the future. In the southern part of the area the Bucatunna is underlain only by salt water.

CAROLINA "SLATE" GROUP AND THE CHARLOTTE BELT IN NEWBERRY COUNTY, SOUTH CAROLINA

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The northwestern edge of the Carolina "slate" group crops out over a 50-square-mile area in southern Newberry County. Rocks of Charlotte belt lithology underlie the remainder of the county.

The "slate" group consists mostly of quartz-sericite phyllites of the greenschist facies. Foliation is parallel to bedding; structures generally trend N.70° E. and are asymmetrical to the northwest. The phyllites are overlain on the northwest by a 1-mile-wide belt in which muscovite quartzite is the dominant rock type. This zone is tightly folded and may be in fault contact with Charlotte belt rocks immediately to the northwest. Pyritic kyanite quartzite is present at Little Mountain. Mechanical deformation and hydrothermal activity may account for the high metamorphic rank of these rocks.

The Charlotte belt rocks consist of amphibolites, quartz-biotite schists, migmatites, and soda-rich granites. Both the asymmetry of the folding and the structural trends are approximately the same as in the "slate" belt. Within 5 miles, across strike, the rocks increase in rank from amphibolites of the epidote amphibolite facies to feldspathic migmatites of the granulite facies. Interbedding of quartz-muscovite schists, quartz-biotite schists, and amphibolites of meta-igneous origin suggests this metamorphic sequence was originally similar in character to the rocks of the "slate" belt.

The migmatites represent a border phase of weakly foliated, partially discordant, medium-grained, soda-rich granite. Steep to vertical contacts, diapirlike structures in the country rock, and disoriented xenoliths indicate considerable mobility after initial granitization, probably during Paleozoic time.

SOME LOCAL CHERTS

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In recent years a number of individuals have called attention to occurrences of chert originating at the early state of pre- or earliest lithification. This paper calls attention to several such examples. These are from:

(1) the upper St. Louis limestone in Lee and Menifee counties where the chert is associated with flow roll structures

(2) the Boyle and Duffin limestones of the southern Bluegrass

(3) the chert beneath the two conspicuous bentonites of the upper Tyrone limestone

NEW ROAD CUTS ON U. S. HIGHWAY 68, MASON COUNTY, KENTUCKY

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Recent road cuts made in rebuilding the highway near Maysville, Mason County, Kentucky, expose an essentially complete section of Upper Eden through Maysville beds.

Many of the excellent faunal zones of the Cincinnati area are recognized here, with some modifications in both lithology and fauna. Reference is made to measured sections in Fleming and Bath counties.

PALYNOLOGY AND ITS APPLICATION TO GEOLOGICAL PROBLEMS IN THE SOUTHEAST

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Palynology, as it concerns the study of plant microfossils, has become a highly regarded tool in the solution of stratigraphic problems. These microfossils, chiefly pollen and spores, may be significant in paleoecological analysis as well as in the interpretation of geomorphic events where the usual stratigraphic criteria are lacking.

The principles and techniques involved in this branch of micropaleontology are not new, and geological application, particularly in Europe, has been well established for some time. Only in recent years has such activity been evident in this country. Diverse problems ranging from Carboniferous coal stratigraphy to Pleistocene climatology have been attacked by this means, and, most recently, considerable interest in these microfossils has developed within the petroleum industry.

During the last few years, the author has been interested in the application of palynological techniques to problems of Southeastern geology. In progress is the development of a biostratigraphic column that may help establish more definite Mesozoic and Cenozoic boundaries. Attention up to this time has been directed mainly toward the stratigraphy of Cretaceous sediments in West Tennessee, and results have been rewarding. Associated paleoecological information is also being assembled.

While lignites and lignitic clays from the northern part of the Mississippi Embayment section have been the principal materials examined, unusual occurrences of such deposits in the Southern Appalachian region have come under scrutiny also. The latter show promise of providing information of a somewhat different, yet nonetheless interesting, nature from which geomorphic inferences may be drawn.

EARTHQUAKES FELT IN KENTUCKY FROM 1776 THROUGH 1959

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The known seismic history of Kentucky dates from the summer of 1776. Since that time, the whole State has been affected perceptibly by five major earthquakes, all centered in other States: (1) the thousands of shocks in 1811–1812, known collectively as the New Madrid earthquake; (2) the Mississippi Valley earthquake of January 4, 1843; (3) the Mississippi Valley earthquake of February 16, 1843; (4) the Charleston, South Carolina, earthquake of August 31, 1886; and (5) the Charleston, Missouri, earthquake of October 18, 1895. In addition to these strong earthquakes, which were felt over very extensive areas in the central and eastern United States, about 200 other earthquakes of low to moderate intensity have affected small to large areas in Kentucky from 1776 through 1959. A large majority of these shocks were centered in other States, mainly in nearby portions of neighboring States; however, several strong earthquakes with distant epicenters, such as the Temiskaming earthquake of November 1, 1935, have been felt at points within the State.

A large percentage of all earthquakes felt in Kentucky are centered in a five-State area in the Mississippi Valley known as the New Madrid seismic area. Most of the others are centered in the Wabash and Ohio river valleys in southwestern Indiana and southeastern Illinois. Shocks centered within the State are limited mainly to the Jackson Purchase region, which is within the New Madrid seismic area. Other sections of the State are essentially stable, and the seismic activity has been limited to a few light shocks.

FOSSIL CINCINNATIAN TRAILS EXPLAINED BY *GONIOBASIS*

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The peculiar fossil trails and markings found commonly in Cincinnatian strata, particularly in the Corryville formation, have been attributed to various bottom-dwelling organisms. So-called

"worm trails" of various dimensions can be duplicated exactly by the modern fresh-water gastropod *Goniobasis*. The abundance of gastropods in close proximity to these trails in Ordovician rocks suggests that the markings were produced by snails.

ELLIPSOIDAL STRUCTURES IN DARK-GRAY SHALE IN WESTERN PENNSYLVANIA

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Thin compressed ellipsoids occur in several sequences of dark-gray shale that overlie coal beds in the Allegheny and Conemaugh formations in Butler and Clarion counties, Pennsylvania. The width of the ellipsoids is always slightly less than the length, which ranges from a quarter of an inch to 6 inches. They are from a thirty-second of an inch to half an inch thick and have depressed centers and sharp margins. Microscopic examination shows them to be composed of the same alternating siltstone and claystone laminae as the enclosing shale. Slickensides radiate convexly from top and bottom axial centers to the equatorial rim. The ellipsoids are flattened in the plane of the bedding of the shale, and their vertical and horizontal distribution in the shale is random.

Organic origin of the ellipsoids as casts, molds, or petrofactions is unlikely because organic structures or imprints are not seen on interior or exterior surfaces. Origin as rain-drop or hail imprints is unlikely because the ellipsoids are not filled cavities. Origin as simple compressed geodes or concretions is discounted because of the absence of mineral fillings or of mineral enrichment. It is believed that the ellipsoids originated as globules of fluid hydrocarbon generated in decaying sapropelic muds and silts, and collected beneath impervious silt and clay laminae. Normal sediment load compressed them to their present dimensions.

BACKSET BEDS IN THE COSO FORMATION, INYO COUNTY, CALIFORNIA

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Some cross-beds in coarse-grained sandstone and pebble conglomerate of the Coso formation (lower Pleistocene) are inclined against the direction of flow of the depositing currents. Textural gradation, mineralogical changes, and structural considerations show that the direction of depositing currents was to the west. About half the cross-beds are inclined to the east, and the other half are inclined to the west. The diametrically opposed directions do not fit the pattern expected of meandering streams. The eastward-inclined cross-beds are called backset beds.

Backset beds are the inclined (planar) type and make an angle of 20° or less with the normal bedding planes. Cross laminations are long tapered wedges with the wide part of the wedge at the base. Material within the wedge is coarse near the bottom and grades to finer material at the top. Normal foreset laminations are either the inclined or festoon (trough) type, and material within each lamination is well sorted and not graded.

The backset beds are believed to have formed during the antidune phase of sediment transport described by G. K. Gilbert. The factors contributing to the antidune phase of sediment transport are high load, high velocity, high resistance, and shallow depth of water. Inasmuch as the deposits were probably deposited in a manner analogous to the heavily overloaded streams of the Basin and Range province today, all these factors could well have been present.

CASE-HISTORY STUDIES OF HOW GEOLOGY AND HYDROLOGY INFLUENCE NUCLEAR-REACTOR SITE LOCATIONS IN FLORIDA

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During the past year the writer worked on three projects concerning site-location studies for proposed nuclear reactors to be located in three areas in Florida. One project involved a generalized

and detailed study of the geologic and hydrologic factors of importance in evaluating a pre-selected area near Pierce, Florida, about 35 miles east of Tampa. A second project involved a similar study of the Ft. Pierce area on the lower east coast. A third project was to find the most favorable sites, geologically and hydrologically, in the broad area including Dixie, Levy, Citrus, and Marion counties.

Favorable geologic and hydrologic factors influencing the safety factors inherent in a given site location were used to evaluate the various possible reactor-site locations. These factors were: (1) quantity and quality of surface and ground water available at any location, (2) topography and drainage characteristics, (3) population affected in the event of accidental spillage of radioactive liquids or solids to the ground, (4) porosity and permeability of the soil and bedrock at each locality, (5) downstream hazards in the event of radioactive contamination of surface or ground water, (6) possible protection the soils may afford toward radioactive decontamination due to their clay content, (7) radioactive dilution potential of surface and ground water in each area.

Several areas in Citrus and Levy counties are identified as having the most favorable geologic and hydrologic characteristics from the standpoint of safety. To these advantages, engineering and economic factors were added to give an over-all rating in each general area.

SEISMIC-REFLECTION SURVEY OF THE SURFACE OF THE BASEMENT COMPLEX IN SOUTHWESTERN INDIANA*

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The Indiana Geological Survey has mapped the surface of the basement complex by seismic-reflection methods in five counties in southwestern Indiana. Records were obtained from 111 stations spaced 1–3 miles apart, and structure maps were constructed on Devonian limestone, Trenton limestone, St. Peter sandstone, and basement-complex surfaces. The structure map on the basement complex shows a regionally smooth slope broken by an elongate northwestward-trending depression with a maximum depth of 3500 feet below the regional slope. This depression ranges in width from 15 to 22 miles and has been traced 35 miles from southwestern Vanderburgh County to northwestern Gibson County. Structure maps on the lower Paleozoic strata show a monoclinal structure over the east flank of the depression. This Paleozoic monocline appears to be a subdued southeastern extension of the west flank of the LaSalle anticline in Illinois. If the basement depression is structurally related to the Paleozoic monocline and if the Paleozoic monocline and LaSalle anticline are part of the same structural unit, the basement depression is structurally related to the LaSalle anticline and extends into Illinois under the west flank of the anticline.

An alternate interpretation of the seismic data is that the reflections defining the basement structure may originate from an intrabasement feature, and the basement surface may be a regionally smooth slope. This interpretation, however, does not explain the presence of a Paleozoic monocline over an intrabasement feature.

USE OF STEP-DRAWDOWN TESTS TO PREDICT YIELDS OF WELLS

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Pumping tests are made as part of the detailed study of ground water in the Huntsville area in north-central Alabama by the U. S. Geological Survey in co-operation with the city of Huntsville and the Geological Survey of Alabama.

The Huntsville area is underlain by massive beds of limestone of Mississippian age that dip southeast at approximately 20 feet per mile, except where local structures exist. Ground water occurs in

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solution cavities developed along fractures and bedding planes in the limestone and in chert gravel overlying the limestone.

Experience has shown that the constant-discharge method of well testing, when applied to wells tapping limestone aquifers in north Alabama, has sometimes resulted in erroneously optimistic conclusions in predicting the performance of a well under higher rates of discharge. The step-drawdown test, which is made by increasing the rate of discharge by equal increments for equal periods of time, provides data that can be analyzed to obtain more accurate predictions of the performance under varying rates of discharge.

From the step-drawdown test the total drawdown at the end of each period is plotted against the corresponding pumping rate and a curve drawn through the points. The drawdown in the well caused by a planned rate of discharge of the same duration may be read directly from the curve. The drawdown for higher discharge rates may be approximated by projecting the curve. The proper pumping equipment and most efficient rates of pumping may be determined from these drawdowns.

ORDOVICIAN CYNTHIANA FORMATION OF CENTRAL KENTUCKY

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Re-examination of the Cynthiana formation in Kentucky has been undertaken to relate the various named members stratigraphically and geographically. The Rogers Gap member is everywhere distinguishable from the rest of the Cynthiana beneath, and its faunal and lithologic relationship to the Fulton (lowest Eden) has been well demonstrated by McFarlan and Freeman (1935). No lower boundary of pre-Rogers Gap Cynthiana rocks has ever been clearly demonstrated, and results of this study indicate that its existence is doubtful. Faunal and lithologic similarities and lack of common boundaries of members indicate that pre-Rogers Gap Cynthiana and upper Lexington—i.e., Perryville (Devil's Hollow) and possibly Woodburn—bear facies relations to one another. It is hoped that the outcome of insoluble-residue studies now in progress will clarify these relationships.

STRUCTURAL INTERPRETATIONS IN THE BIRMINGHAM RED IRON ORE DISTRICT, ALABAMA

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The Birmingham Red Iron Ore district, Alabama, is characterized by a series of parallel ridges and valleys that trend northeast. Ridges that form Red, Little Shades, and Shades mountains are typical hogbacks with steep northwest escarpments and gentle southeast dip slopes.

Rocks that crop out in the area range in age from Cambrian to Pennsylvanian. The oldest rocks are predominantly carbonate shelf-type sediments, and the youngest are clastic geosynclinal sediments. These rocks have been extensively folded and faulted into typical Ridge and Valley structures of the Appalachian type.

The parallelism of the northeasterly trending folds and faults suggests a common origin. Study of the joint systems and their relation to the folds and faults revealed that initial deformation was the result of compressional forces originating in a southeasterly direction. However, further analysis revealed a subsequent stress system, originating in compression from the south, that acted as a shear couple. This shear is manifested by strike-slip movement along most of the faults of the district and by a secondary joint system in the rocks contiguous to the major faults.

DISTRIBUTION OF "ST. PETER-TYPE" SAND IN SILURIAN AND DEVONIAN OF CENTRAL KENTUCKY

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Studies of insoluble residues of Silurian and Devonian carbonate formations in Ohio show the presence of "St. Peter-type" sand grains. The well-rounded, frosted grains are found at the base of

the Devonian, at disconformities within the Devonian, and scattered as "floaters" throughout Devonian formations. Thus far the "St. Peter-type" sands have not been found in a Silurian formation. Insoluble residues of Silurian and Devonian sections bordering the Jessamine Dome of central Kentucky show the same pattern of stratigraphic distribution. Here the most persistent concentration of frosted grains occurs in the Kiddville layer. Similar but less well-developed concentrations occur locally at the base of the Devonian.

Subsurface study of well cuttings from counties flanking the Cincinnati arch substantiates the stratigraphic distribution of the sand in outcrop.

The source of the sand is interpreted to be the St. Peter formation in the Ozark and Wisconsin highlands. Shore currents, waves, and probably some wind action transported the sands eastward, concentrating the sand deposits along the shores and shallows of the Devonian island Cincinnatia.

EMPLACEMENT OF GRANITIC PLUTONS IN NORTHEASTERN OREGON

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Twenty-nine months of field studies in northeastern Oregon indicates that forceful intrusion was the dominant emplacement mechanism for nearly all granitic plutons. Stoping contributed to emplacement but was subordinate. In some areas, minor granitization occurred as a by-product of magmatic intrusion. Field evidence refutes Dickson's (1958) theory of "zone melting" as an emplacement mechanism of major significance for any of the larger plutons. Field studies of some relatively small leucocratic plutons within the composite batholiths give no definite evidence concerning the dominant emplacement mechanism.

Evidence for forceful intrusion includes structural features of granite tectonics, marked deflection of structural trends around plutons, and visible deflection of bedding in country rocks near the ends of apophyses and small sills. Stretched pebbles near some granitic contacts and S-shaped beds of limestone at right angles to other contacts also attest to forceful intrusion.

Photographs, sketches of photographs and field relations, geologic maps, and hand specimens illustrate evidence for forceful emplacement of granitic rocks in the Bald Mountain batholith, Wallowa batholith, and Cornucopia stock and in their respective satellitic bodies.

GEOLOGIC MAPPING WITH AERIAL PHOTOGRAPHS IN THE ANTHRACITE REGION OF EASTERN PENNSYLVANIA

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Geologists of the U. S. Geological Survey have found aerial photographs extremely useful in mapping the complex geology of the anthracite fields of Pennsylvania despite extensive cover and vegetation. Minor intraformational variations in lithology, which generally cannot be mapped or correlated in the field on topographic maps, are readily visible and mappable on aerial photographs when a stereoscope is used.

The Pottsville and Pocono formations consist of massive conglomerate and sandstone beds with thin units of siltstone, shale, and coal. The resistant sandstone and conglomerate beds generally underlie subtle but persistent benches or ridges visible on aerial photographs but commonly not delineated on topographic maps. Shale and coal beds underlie the intervening low areas. By tracing these features in the field an extremely detailed geologic field map is compiled in which most of the units having topographic expression can be accurately mapped and correlated from exposure to exposure. By mapping many of these intraformational units subtle geologic structures have been recognized such as folded and unfolded thrust faults whose traces strike nearly parallel to bedding. In addition, unconformities and facies changes have also been recognized.

Similarly, the red beds of the Catskill and Mauch Chunk formations have alternating units of contrasting erosional resistance which are commonly visible on aerial photographs. Detailed mapping

of these units indicates lithologic changes and structural features within these formations which might otherwise have been missed. Dividing a formation into small topographically expressed lithologic units visible on aerial photographs has made possible the accurate mapping of stratigraphic changes and intraformational structures.

FENESTRATE BRYOZOANS FROM THE GLEN DEAN LIMESTONE (MIDDLE CHESTER) OF SOUTHERN INDIANA

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Fenestrate bryozoans are particularly abundant in shale and argillaceous limestone beds in the upper part of the Glen Dean limestone (middle Chester) of south-central Indiana. All specimens are assigned to the genera *Fenestella* Lonsdale, *Polypora* McCoy, *Septopora* Prout, and *Lyroporella* Simpson. The most abundantly represented genus is *Fenestella* in which five species, *F. exigua* Ulrich, *F. tenax* Ulrich, *F. matheri* Condra and Elias, *F. cestriensis* Ulrich, and *F. burlingtonensis* Ulrich, are recognized. *Polypora* is the next most abundant genus.

Frequency-distribution diagrams showing number of branches and fenestrules in 10 mm and number of zooecia and nodes in 5 mm have been prepared for each species. Such diagrams permit clearer differentiation among closely allied species in which the ranges of one or more structural characters may overlap. Further, these diagrams present a conceptually more accurate understanding of each species.

The fenestrate bryozoan fauna, as known from 3 excellent collecting localities, includes about 11 species, exclusive of species of *Archimedes* Owen which were not included in this study. Although fenestrate bryozoan faunas have been described in considerable detail from Glen Dean beds in Illinois, Ohio, and Kentucky, these faunal elements of the Glen Dean of Indiana have hitherto not received significant attention.

STRATIGRAPHIC POSITION OF THE OHIO RIVER FORMATION IN INDIANA AND KENTUCKY*

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The Ohio River formation is a body of poorly consolidated medium- to fine-grained quartz sand in southern Indiana and northern Kentucky. It overlies middle Mississippian limestones in a narrow belt from near Salem, Indiana, to south of Fort Knox, Kentucky. Although it is regarded as a "ridge top" sand, it does not cap the highest hills. It was beveled along with the surrounding rocks during the late Tertiary cycle of erosion; remnants of the formation range from a few inches to more than 80 feet in thickness. This sand body is better sorted than the sandstone in either the Big Clifty formation of the Chester series or the Mansfield formation of the Pottsville series, with both of which it has been compared. Physical characteristics of the formation are more similar to beach and dune sands than to sand deposits of other environments. As it contains no known fossils, its correlation must depend on physical criteria and paleogeographic interpretations. The only regional submergence during which the Gulf Embayment could have extended far enough inland to have provided deposition in this area took place during the Paleocene epoch, when the Porter's Creek clay was laid down in western Kentucky. Major source of the sand probably was sandstones of the Chester and Pottsville series, which undoubtedly were present this far eastward during the early part of the Tertiary period. A thick, cherty, conglomeratic clay that separates the sand from the underlying limestone probably is residuum that mantled a late Cretaceous erosion surface.

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SEQUATCHIE AND ROCKWOOD FORMATIONS IN SOUTHEAST TENNESSEE AND PART OF NORTHWEST GEORGIA

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The Rockwood formation, named by Hayes in 1894 for the strata above the Chickamauga limestone and below the Chattanooga shale, was divided by Ulrich in 1911 into the Sequatchie and Rockwood (restricted) formations. These formations or their equivalents were examined at about 100 localities in southeast Tennessee and part of northwest Georgia—chiefly (1) in Sequatchie Valley, (2) along the base of the Cumberland escarpment, and (3) in the Whiteoak Mountain-Chamberlain belt in the middle of the Appalachian Valley.

The Upper Ordovician (Richmond) Sequatchie formation ranges in thickness from about 100 to more than 300 feet. It contains (1) reddish limy and clastic marine equivalents of the Juniata formation that enter the study area from the northeast, and (2) limy and shaly locally ferruginous equivalents of the Fernvale formation or Mannie shale that enter from the west. The formation appears to be conformable with underlying Cincinnatian strata but apparently was eroded locally at the top prior to Rockwood sedimentation.

The Lower and Middle Silurian (Brassfield-Clinton) Rockwood formation overlies the Sequatchie unconformably and ranges in thickness from about 1000 feet in the southeast to 20 feet or less in the northwest. Thicker coarse clastic eastern strata grade westward into a locally cherty limestone–shale facies. Relatively thin beds of Clinton-type iron ore are present in most of the study area, chiefly in the Brassfield equivalents. Clinton equivalents in the Rockwood of the area are more widespread than previously supposed. Although some of the northwestward thinning is due to facies change, some is also caused by pre-Chattanooga erosion.

CLASSIFICATION OF THE LIMESTONES OF THE TYPE CINCINNATIAN

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The abundant ledges of limestone characteristic of the type Cincinnatian in the Ohio Valley can be grouped into several classes on the basis of a few criteria that are readily recognized in the hand specimen. Such a classification can make rock descriptions much simpler for those who measure sections there; furthermore, closer correspondence is now possible between the rock descriptions used or published by different workers. The petrographic properties of the seven classes are fully described and illustrated, although the limestone types are readily distinguished as follows:

(1) Fabric of whole and broken fossils randomly arranged; insoluble fraction small and localized

(2) Fabric of broken and whole fossils oriented parallel to bedding; insoluble fraction moderate in amount and localized or disseminated

(3) Fabric of whole and broken fossils, either oriented or randomly arranged; insoluble fraction large

(4) Fabric of finely broken fossil debris; insoluble fraction small and disseminated

(5) Fabric of finely broken fossil debris; insoluble fraction moderate to large; rock laminated or cross-laminated

(6) Fabric of very finely broken fossil debris; insoluble fraction large

(7) Like number 6, but occurs as nodules.

Rocks of the several classes make up the following approximate percentages of about 1800 samples of Cynthiana and Eden limestones: 1:40; 2:25; 3:5; 4:8; 5:15; 6:5; and 7:3.

MAJOR FOLDS BY SOLUTION IN THE WESTERN HIGHLAND RIM OF TENNESSEE

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As Miser observed, his geologic map of the Waynesboro quadrangle shows most streams following the axes of synclines, each of which plunges downstream at the same rate of declivity as the fall of its stream.

For the following reasons, I believe these synclines result from differential settling caused by solution.

(1) The youngest exposed Paleozoic strata are on anticlinal crests; the oldest, in synclinal troughs. If these folds had been made by pre-Cretaceous tectonic forces, they should have been bevelled by the erosion surface on which the Tuscaloosa rests and perhaps again by the Highland Rim surface. The synclines should still preserve remnants of infolded younger Paleozoic rocks; they do not.

(2) The amplitude of synclines increases downstream.

(3) Synclines increase in complexity downstream.

(4) Synclines branch with the streams that occupy them, and all end at the heads of the streams.

(5) The syncline which follows Buffalo River and its tributary Green River makes two right-angled bends where the river is offset by a lineament which suggests control by solution along a master joint or fault.

(6) The biggest fold is an anticline which follows the principal divide (between Shoal Creek and the Tennessee River). It is still largely capped with Cretaceous remnants. Axes of the lesser folds radiate from this larger one, a pattern that suggests solution along the stream courses and vertical adjustment to gravity rather than lateral compression.

(7) There are small, nearly equidimensional structural highs and lows within both synclines and anticlines. These also suggest differential settling.

GEOCHEMICAL METHODS FOR DEFINING GROUND-WATER FLOW

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The direction and relative magnitude of ground-water flow through an aquifer commonly is determined from a water-level contour map based on measurements of water levels in wells. Where water-level measurements are difficult to obtain, chemical data from readily available water samples may be used to supplement water-level measurements as a means of defining ground-water flow patterns. The quality of water in an aquifer may change chemically, because of the reaction of the water with the soluble constituents of the host rock, or physically, because of replacement of water of one chemical quality by flushing or intrusion of water of another chemical quality.

Chemical change in water quality is illustrated in Martin County, North Carolina, where acidic iron-bearing waters from a water-table aquifer of surficial sand recharge an underlying artesian aquifer of calcareous marl. The pH of the water increases as it passes through and dissolves calcareous material from the marl. The increase in pH results in the precipitation of iron, and it changes the Eh value (oxidation-reduction potential) of the water. In a hydrologic environment, where there is a relationship between dissolved iron and the Eh and pH of the water, the field measurement of Eh can be used directly to separate areas of ground-water recharge and thus delineate ground-water flow patterns.

Physical change in water quality is illustrated in Volusia County, Florida, where fresh water is replacing salty water in an artesian aquifer. Field analysis of the chloride content of water samples in the area were used to construct a map of the chloride content of the artesian aquifer. The correlation between the map of the chloride content and piezometric map is excellent and suggests that chloride measurements may be used in some areas to delineate ground-water flow patterns in the absence of water-level measurements as well as to supplement available measurements.

ABSTRACTS OF PAPERS SUBMITTED FOR THE MEETING IN RAPID CITY, SOUTH DAKOTA, APRIL 28–30, 1960

ROCKY MOUNTAIN SECTION (GSA)

AGE AND REGIONAL RELATIONSHIPS OF THE INDEPENDENCE MOUNTAIN FAULT, NORTH PARK BASIN, COLORADO

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The northern termination of North Park Basin, Colorado, is the low-angle, north-dipping, N. 65° W. trending Independence Mountain fault mappable for 20 miles in T. 11 N., Rs. 79–81 W. The thrust is restricted to the south side of the shear zone trending N. 50° E. which transects the Park Range north of Mt. Zirkel. The shear zone parallels North Fork of Elk River and is delimited by mineralization and infaulted sediments. The Independence Mountain thrust trace is deeply indented coincident with the course of Parsons Draw where Precambrian gneisses of the thrust plate rest on all formations from Triassic Chugwater to Paleocene Coalmont. The Coalmont is locally discordant upon beds as old as Mowry shale, is folded steeply into the North Park syncline, and overlaps regionally onto Precambrian.

Fault slices of Triassic Chugwater formation beneath the thrust plate delimit the fault trace east and west of Parsons Draw. Structure contours on the Dakota sandstone indicate subthrust folding and normal faulting in Parsons Draw before thrust-plate emplacement. Previous interpretations of simple structure in a fenster are not tenable.

High ridges south of, adjacent to, and topographically higher than the thrust trace are capped by boulder deposits shed from the thrust but previously considered to overlap its trace. Isolated Precambrian rocks resting on the Coalmont south of, and at lower elevations than, the thrust trace have been emplaced by gravity sliding.

The thrust is post-Paleocene and pre-Oligocene. Normal faults of post-late Miocene age offset both the thrust trace and the high-level boulder beds.

STRATIGRAPHIC SECTIONS OF THE IDAHO SPRINGS WEST OF DENVER, COLORADO

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A synclinal trough containing thick, closely folded Precambrian metasedimentary strata of Idaho Springs age extends generally northwest–southeast between the south end of Boulder Creek batholith and Indian Creek plutons, of Silver Plume-type granite, on the south, and Mt. Evans batholith of Boulder Creek-type granite, on the southwest. This trough terminates at the northwest against the northeast-trending structures at the Central Mineral Belt of Colorado.

Sections measured southwest–northeast across the southwest flank of the irregular trough show three calcareous zones each consisting of marble, marmorite, tactite, skarn, quartzite, colored silexite, and para-amphibolite. Each calcareous member is continuous along strike but laterally variable in lithology and mineralogy.

The separation of the Idaho Springs into formations is based on (1) the individuality of lithologic sections within the stratigraphic sequence, (2) superposition, (3) the general north to northeast dip of the formations away from the interlocking mass of granite at the southwest, (4) persistence along strike of each calcareous member and associated strata for 20 to 24 miles across the east flank of Front Range west of Denver. The proposed subdivisions agree with the three stratigraphic units described by Ball in 1908 in the Idaho Springs formation west of Denver Mountain Parks and with the three calcareous zones of the A series of Wahlstrom and Kim in the Hall Valley Precambrian 25 miles to the southwest.

SOLUTION BRECCIAS IN THE UPPER PART OF THE MINNELUSA SANDSTONE, SOUTH DAKOTA AND WYOMING

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In the southern Black Hills of South Dakota and Wyoming, solution and removal by ground water of nearly 250 feet of anhydrite have resulted in widespread brecciation and collapse of the upper part of the Minnelusa sandstone. Brecciation is most intense in the interval between the "Converse sands" and the underlying "Red Marker" where as much as 160 feet of anhydrite, constituting 50 per cent of the subsurface section, has been removed. Subsidence features are sheet breccia, breccia pipes and "sills", crenulated beds, boxwork, and solution cavities.

Collapse features in the 1200 to 1600 feet of overlying rocks of the Opeche, Minnekahta, Spearfish, Sundance, Unkpapa, Morrison, Lakota, and Fall River formations are attributed to the solution of calcium sulfate in the Minnelusa. Anhydrite or gypsum beds in the Spearfish formation have not been extensively dissolved by ground water because circulation is restricted by siltstones of low permeability. Highly permeable sandstones associated with the anhydrite doubtless assisted the widespread solution in the Minnelusa.

Sinkholes, formed during Recent time, and the relatively large quantities of $CaSO_4$ carried in present-day spring waters indicate that solution and subsidence begun by the uplift of the Black Hills is continuing down dip from the brecciated outcrops.

FOSSIL PLANTS (?) IN THE TRIASSIC CHUGWATER FORMATION

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During the past 2 years, many patterned surfaces thought to be molds of plant structures have been collected from red strata of the Red Peak member of the Chugwater formation. The specimens are of special interest because of uncertainty concerning the depositional environment of the Red Peak member, a unit long regarded as unfossiliferous.

Most of the objects are asymmetrical, conical bodies of siltstone with a maximum diameter of 2-6 inches. They are oriented apex down and bear on their sloping surfaces a complex branching pattern of ridges analogous to the vein system of a leaf.

Specimens have been collected from 24 widely scattered localities in Wyoming and northern Colorado. They occur in the upper 425 feet of the Red Peak member and stratigraphic equivalents in distinctive, massive ledges of siltstone characterized by irregular, discontinuous bedding.

Similarities to burrow fillings and to various inorganic features are outnumbered by dissimilarities involving pattern details, orientation, relationships to other structures, and nature of the enclosing strata. The specimens probably originated when water-borne sediment accumulated on and around plants, preserving them in growth position. The plants are interpreted as having had irregularly cylindrical bases several inches in diameter from which emanated leaflike structures with a branching pattern of ridges on their under surfaces. Each conical fossil probably represents sediment deposited on the cup-shaped surface of a partly developed "leaf". The fully expanded "leaves" were probably as much as 2 feet long. No evidence of woody structure or carbon has been found.

FIELD INTERPRETATION OF POST-SILURIAN RED BEDS

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Seven types of red beds, with different paleogeographic interpretations, can be recognized in the field: (1) shale-pebble conglomerates, with red color inherited from pre-existing red beds; (2) red-clay conglomerates, with red color derived from laterites in the source area; (3) variegated red beds, developed in fluvial deposits forming under equable climates with seasonal rainfall; (4) cinnamon-red

beds, probably formed in shallow-water marine environments of wide areal extent; (5) brick-red beds, littoral and deltaic facies of (4); (6) pastel red beds, a sharply defined facies of unknown origin; (7) spattered red beds, in which the red color has been introduced after deposition.

These seven facies are described, and typical horizons and localities are given for each. This classification of red beds is intended primarily for field use; it does not supplant the excellent theoretical and genetic classifications of Krynine and others.

PARQUE CENTRAL, SANTA BARBARA, VILLA PABON LANDSLIDE AREA, LA PAZ, BOLIVIA

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The Parque Central, Santa Barbara, Villa Pabon landslide area is in the central part of the city of La Paz, Bolivia. Topographic relief between the toe and the scarp of the landslide complex is about 250 m. Materials involved are Pleistocene clays, silts, sands, gravels, and artificial fill composed of a mixture of all these materials. Within the landslide complex is a block that was displaced in later Pleistocene time. A side of this block adjacent to a river sloughs as a result of undercutting, but the core is inactive. Parts of the landslide area have been active intermittently since the founding of La Paz in 1548.

At times in the past, displacements have separated city water-supply mains, power lines, and important land-communication routes leading eastward from the city. In consequence of impairment of service facilities and communication, some larger suburbs have been isolated for several days at a time.

The landslides are active near the end of the rainy season during years when precipitation is higher than average. Causes of the landslide are: oversteepening of the valley resulting from deep incision by youthful streams, inherent weakness of the poorly consolidated materials, infiltration of meteoric water, and malpractice in providing surface drainage. Recommended corrective measures are: more effective location of surface drainage, installation of subsurface interception drains, and installation of wells that are to be pumped, particularly during the rainy season.

USE OF CHEMICAL ANALYSIS FOR CORRELATION OF CARBONATE ROCKS

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It is often difficult to determine the mineralogy of carbonate rocks. Chemical analysis can be used to determine the mineral types and relative abundance of each.

Detailed chemical analysis is costly and time consuming. A modified method was developed to determine the total insolubles, R_2O_3, and MgO/CaO. Total insolubles were determined by dissolving the sample in concentrated HCl and HNO_3, then adding perchloric acid and heating to dehydrate the silica present. The R_2O_3 group was determined by precipitation with ammonium hydroxide. MgO/CaO was determined by EDTA titration. Analysis of National Bureau of Standards samples gave good results.

The minerals in a carbonate rock may be either primary, because of the processes of deposition and diagenesis, or secondary, because of metasomatic changes after lithification. If little or no post-lithification alteration has occurred, chemical analysis of a carbonate rock should be a useful tool for correlations.

If the carbonate rock is relatively unaltered, the total insolubles and R_2O_3 will reflect minerals admixed during deposition or formed during diagenesis. The amounts of total insolubles and R_2O_3 should be uniform laterally since they represent the conditions under which the rock formed. MgO/CaO is less useful for correlation. Diagenetic and post-lithification dolomitization can be very similar in their end result.

Satisfactory results were obtained for short-range correlations of the Pahasapa formation.

GEOLOGIC INTERPRETATION OF THE HEBGEN LAKE EARTHQUAKE, MONTANA

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The Hebgen Lake earthquake occurred in a zone of seismicity that extends from Arizona to Canada. In Montana this zone is one of regional uplift and local subsidence, and is characterized by late Cenozoic block faulting and gentle warping. Many of the intermontane basins are bounded on at least one side by large normal faults showing late Cenozoic movement. At Hebgen Lake folds and thrust faults of Laramide age have controlled the location of younger normal faults, some of which were reactivated during the earthquake. A maximum absolute subsidence of 19 feet was measured by precise levels northeast of Hebgen Lake; and on the western margin of the Madison Range, the Madison Range fault was reactivated so as to drop part of the Madison Valley. The net result was to increase the relief of the Madison Range between Hebgen Lake and Madison Valley. This suggests that the basin- and range-forming process is still going on. Warping, which occurred during the earthquake, is dependent on the faulting. Warp axes, transverse and parallel to the faults, are detectable in the subsided and differentially tilted Hebgen Lake block. Warping nowhere exceeds ¾° along the fault zone, and generally is much less. The sag is greatest near the medial part of the fault zone and diminishes systematically away from it.

CORRELATION OF UNITS IN THE LOWER PART OF THE PIERRE SHALE, GREAT PLAINS REGION

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The Sharon Springs member of the Pierre shale is the lowermost unit of the formation along the Missouri River in central South Dakota and along the flanks of the southern half of the Black Hills. The Mitten black shale member and the underlying Gammon ferruginous member form the lower part of the Pierre shale along the northern part of the Black Hills.

The Sharon Springs member and the lower part of the Mitten black shale member are equivalent in age and consist of conspicuously organic-rich black shale. Both contain beds of nonswelling bentonite and have distinctive gamma-ray and electric-log characteristics. The members may be correlated in the subsurface throughout much of North Dakota, and South Dakota, the eastern parts of Montana, Wyoming, and Colorado, and the western parts of Nebraska and Kansas.

Along the Missouri River in central South Dakota, the Sharon Springs member conformably overlies calcareous rocks of the Niobrara formation at most places. Not far west of the Missouri River, the Gammon ferruginous member, a wedge of generally noncalcareous gray ironstone-bearing shale, appears between the Sharon Springs and Niobrara and thickens to the northwest. The Gammon ferruginous member is 1000 feet thick or more in the northern Black Hills; it is conformable beneath the Sharon Springs and interfingers or is gradational with the Niobrara. The Gammon wedges out within a short distance southward along the east and west flanks of the Black Hills. In the vicinity of Newcastle, Wyoming, the unit thins from 600 feet to the vanishing point in a southeasterly direction within a distance of less than 10 miles.

NORTH MISSILE SITE WATER WELLS

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The United States Government contracted for two water wells, to furnish the water supply for a missile site, to be drilled on Sec 19, T. 5 N., R. 7 E., Black Hills Meridian.

The first well was drilled and flowed at the rate of 5 gallons per minute, but the drill-stem test

indicated that there was an abundance of water in the Lakota formation at a depth between 1582 and 1782 feet. The well produced only 28 gallons per minute, even after water-facing and jetting the formation.

It was decided to drill the second well to the Pahasapa formation where a good supply of water was known to exist at a depth below 3650 feet. A small water loss was encountered between 3102 and 3120 feet at the top of the Minnelusa formation, and at a depth of 3161 feet the drill bit dropped 4 feet, and a water flow of about 4000 gallons per minute caused a discontinuation of the drilling.

The flow of the water was brought under control by the use of heavy mud, chemicals, and a string of 7-inch casing that was set through the water, cemented in place, and perforated with 240 jets between 3095 and 3155 feet.

A production string of 3½-inch tubing was set to a depth of 665 feet with a Baker Packer and Page Valve, and the final flow is 748 gallons per minute of 68-degree water with a closed-in pressure of 160 pounds. Surface elevation is 2955 feet.

LAKE BONNEVILLE: A PRELIMINARY REPORT ON THE QUATERNARY DEPOSITS OF LITTLE VALLEY, PROMONTORY RANGE, UTAH

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In order to provide fill for the railroad causeway across Great Salt Lake, about 28,000,000 cubic yards of gravel, sand, and silt was removed in a longitudinal trench in the lower (western) part of Little Valley near the south end of Promontory Range. The cut extends from below the Stansbury level nearly to the Bonneville level and is the longest continuous exposure of deposits in this significant segment of lake-level fluctuations.

A pink marker bed, three or more buried soils, and two or three ash beds, one of which may be equivalent to the Pearlette, render the section extremely attractive for the deciphering of Quaternary chronology in the eastern Great Basin.

The basal Pleistocene deposits consist of lake gravel, volcanic ash, and alluvial-colluvial deposits. Ash from these deposits is similar to ash found by Eardley and Gvosdetsky at a depth of 550 feet in a well core at Saltair on Great Salt Lake. A strong pre-Wisconsin soil was developed on the basal Pleistocene deposits at Little Valley.

Deposits of the Lake Bonneville group overlie the pre-Wisconsin soil. They include a heretofore unrecognized gravel which shows that Lake Bonneville stood at the Provo level and built a sizable spit before the lake rose to the high levels of the Intermediate (Alpine) and Bonneville stages.

After Lake Bonneville overflowed and receded below the Stansbury level, Little Valley was covered by alluvium on which a soil developed. During a later rise, the lake deposited materials as high as the Stansbury level.

URANIUM DEPOSITS OF THE SOUTHWESTERN BLACK HILLS

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Both uraninite and carnotite deposits have been mined from four principal stratigraphic units of the Inyan Kara group (Lower Cretaceous) in the southwestern Black Hills. These are the oldest (S_1) and youngest (S_4) sandstones of the Lakota formation, the oldest (S_6) sandstone in the Fall River formation, and the carbonaceous siltstone and sandstone unit that underlies S_6.

Uranium migrated in solution vertically through breccia pipes or fault zones and laterally through permeable channel sandstones of the Inyan Kara group. The S_1 and S_4 sandstones appear to have been the principal conduits for these uraniferous solutions.

The localization of some of the deposits was controlled structurally, as on the western edge of the

Gull terrace, in the faulted area in the south-central part of the Edgemont NE quadrangle, and on the Chilson anticline, particularly at collapsed zones near its crest. Other deposits appear to have been localized by the intermingling of chemically different waters at the intersection of two channel sandstones such as S_4 and S_5 or S_5 and S_6.

Alteration halos of pink hematite stain, of carbonate cement, or of silica cement in rocks that have had a history of production are valuable guides for exploration.

The preservation of a uranium deposit requires the maintenance of reducing conditions in the rock, or the availability of vanadium to form insoluble compounds with uranium during the oxidation of a deposit.

STRUCTURAL, TEXTURAL, MINERALOGICAL, AND CHEMICAL CHANGES IN PRECAMBRIAN GRANITIZED ROCKS IN CENTRAL TEXAS AND COLORADO FRONT RANGE

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Outcrop features, petrographic data, and chemical analyses of rocks from the following selected localities are discussed: (1) northwesternmost portion of Legion Creek batholith, Llano County, Texas; (2) Sixmile pluton, Llano County, Texas; (3) Kennedy Gulch, Jefferson County, Colorado; and (4) Shaffer's Crossing, Jefferson County, Colorado.

At locality (1) there has been recrystallization from biotite-quartz-andesine gneiss to quartz diorite without additive metasomatism. Lens-shaped recrystallization zones of quartz diorite have developed concordantly with foliation of metamorphic wall rocks. Small-scale local embayments of quartz diorite cut discordantly across foliation and banding structures in the metamorphic wall rocks. Contact of quartz diorite is sharp at the immediate contact face of the advancing recrystallization front which is convex toward the schist. Slight foliated structure yet remains in the quartz diorite.

At locality (2) foliation of metamorphic wall rocks has guided intrusion of a 300-foot thick tongue of leuco-quartz monzonite into hornblende-biotite-quartz-microcline-andesine schist. A zone of metamorphism of about 50 feet occurs between the intrusive and the metamorphic wall rock. Replacement of metamorphic wall rocks occurred via addition of K_2O to hornblende-biotite-quartz-andesine schist accompanied by recrystallization of quartz and metamorphic segregation and local concentration of calco-ferromagnesian minerals. Toward the intrusive rock, basic selvages commonly grade from quartz diorite to leuco granodiorite to leuco-quartz monzonite.

Locality (3) has changes similar to locality (2) but on a smaller scale. *S*-tectonite has become *R*-tectonite. At locality (4) potash metasomatism of amphibolite formed biotite-quartz monzonite with occasional narrow biotite selvages.

EARLY CRETACEOUS FOLDING ON THE WEST FLANK OF THE BLACK HILLS, WYOMING

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Early Cretaceous folding is indicated by local angular unconformities at the base of the Lower Cretaceous Lakota and Fall River formations at two localities on the west flank of the Black Hills. One locality is a small dome in Barlow Canyon in T. 54 N., R. 65 W., Crook County, about 2 miles north of Devils Tower, Wyoming. There the Morrison formation and part of the Redwater shale member of the Sundance formation of Late Jurassic age are trucated beneath a local angular unconformity that dies out laterally in the basal part of the overlying Lakota formation. Pre-Lakota structural relief in this area is about 250 feet in a mile.

The second locality is a small dome along Oil Creek in T. 47 N., R. 62 W., Weston County, about 8 miles northwest of Newcastle, Wyoming, where the upper part of the Lakota formation is truncated beneath an angular unconformity at the base of the Fall River formation. Pre-Fall River structural relief in this area is at least 120 feet in half a mile.

SEISMICITY OF THE GREAT PLAINS IN RELATION TO REGIONAL GEOLOGIC STRUCTURE

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More than 275 earthquakes have been reported in the region between the Mississippi Valley and the Rocky Mountains in the period 1924–1959. The most active area is a two-branched zone along the Mississippi River from Memphis, Tennessee, to St. Louis, Missouri. The lower and more active branch trends N. 20° E. from Memphis to Cairo, Illinois, and terminates abruptly in the south at Memphis, where a possible extension of the seismically inactive Ouachita Mountains passes under the Mississippi Embayment. The northern branch trends from New Madrid to St. Louis, Missouri. Slight activity continues to the north along the Mississippi River to northern Illinois. The Ouachita Mountains are seismically quiet, with a line of earthquakes along the southern border. Seismic zones occur along the Gulf Coast, in the Oklahoma City region where unusually high activity may be due to the junction of the active Amarillo and Nemaha structures, around the Black Hills Uplift, and around the Sioux Uplift, particularly along the western edge. The fault systems in Texas are seismically quiet except in the Big Bend and Amarillo regions.

Intensities of the earthquakes are low; 30 of them have intensities above V, and only one reaches VIII on the Modified Mercalli scale, but the felt areas are frequently exceptionally great. Earthquake sounds accompanied at least 50 quakes.

HEBGEN LAKE, MONTANA, EARTHQUAKE—RESULTS OBTAINED FROM COAST AND GEODETIC SURVEY INVESTIGATIONS

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Results from the Coast and Geodetic Survey investigations of the 1959 Hebgen Lake, Montana, earthquakes include studies of the seismic history of the area, an isoseismal map of the main shock of August 18, 1959, and the instrumentally determined epicenters of the main shock and some major aftershocks. Other subjects include the results of the analysis of the strong-motion seismograph records obtained from these earthquakes, of the releveling survey run along Montana State Highway 1, and of a special aerial-photography survey flown over the central area. Surface effects and structural damage are illustrated.

STRATIGRAPHY AND STRUCTURE OF THE PICK RANCH AREA, CARBON COUNTY, WYOMING

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Cenozoic formations at Pick Ranch in the Saratoga Basin, Wyoming, aggregate more than 2500 feet in thickness. Mid-Miocene (Hemingfordian) Browns Park basal conglomerate and sandstone, middle gray ferruginous sandstone, and upper green magnetite-bearing sandstone units are conformably overlain by the North Park formation, predominantly late Miocene (Barstovian) in age. A prominent resistant chalcedonic ledge and associated sandy limestone form the basal North Park unit. Successive distinctive overlying lithologies include lower tan medium-grained calcareous sandstone, bearing sporadic volcanic flow-rock grains, olive-drab to brown fissile shale interbedded in some zones with nodular limestone, and an upper variable sequence of tan, green, to white, medium- to fine-grained siliceous or calcareous tuffaceous sandstone, calcareous sandstone, and thin white limestone.

Abundance of thin beds and fine-grained sediments are best attributed to basinward lacustrine conditions which are in marked contrast to equivalent but much coarser fluviatile and talus materials upstream (southward) or nearer mountain flanks.

A series of generally north-trending normal faults, some showing scissor movement, causes three partial section repetitions; grabens and horsts are related complications. Although North Platte River alluvium intervenes southward, this fault system projects toward normal faults 5 miles west of Saratoga that cut supposed Pleistocene surfaces. Faults at Pick Ranch are attributed to tension involved in northeastward tilt or collapse of Saratoga Basin away from Miller Hill to the west, toward a flexure line near the east side of the basin.

WATER OF COMPACTION AS AN ORE-FORMING FLUID

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Sedimentary-type ore deposits of problematical origin, including sandstone-type deposits of uranium, vanadium, and copper, and Mississippi Valley-type deposits of lead and zinc, may have been formed by lateral migration of water of compaction. Extraction by connate water of ore elements known to be present in sediments appears more logical than the assumption that these ore elements were supplied by solutions introduced along unseen conduits from hypothetical igneous sources.

It is postulated that ore elements are acquired by connate water, during diagenesis of sediments, and carried along as the water is expelled during compaction of the source beds. Expulsion of this enriched fluid probably takes place down a hydrodynamic gradient established during compaction of shales and is concentrated through relatively transmissive units. As the fluid moves down the pressure gradient, gases may be exsolved, or disequilibrium may be brought about in the fluid, and either, or both, may cause precipitation of ore minerals. Adsorption by clay or carbonaceous material probably in the presence of a reducing agent such as H_2S appears to be a critical factor in the formation of many deposits.

Mineral belts may thus represent zones in which pressure conditions were favorable for deposition of ore from water of compaction being discharged through transmissive beds. Application of this concept may find use in guiding exploration and in estimating potential ore reserves.

SURFACE FAULTING IN RECENT EARTHQUAKES, WESTERN CORDILLERA

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Most strong earthquakes (Richter magnitude 6, plus) in the Western Cordillera are accompanied by surface faulting. In all surface faults seen in the field, geological evidence was conclusive that movements causing the earthquakes were but the latest in an active, established fault zone.

Fault movement appears to start by rock rupturing at a focal point and progresses in two dimensions to form a rough plane. If the focus is shallow and the energy of the earthquake is sufficient, this fault plane is extended to the surface. As the break approaches the surface, more heterogeneous rock, weathered rock, soil, and, finally, irregular topography are encountered. Consequently, surface ruptures along a fault trace are discontinuous, and a single fracture may extend for only a distance of a few feet to a mile or more. En echelon arrangement of fractures within a fault zone is common. In faults with an appreciable vertical component of movement, the height of scarp developed along the trace is highly variable. Maximum scarps are formed in shallow alluvial materials in small valleys crossed by the fault trace; minimum scarps are developed in bedrock and where a fault trace crosses a ridge; fault ruptures are apt to be completely absorbed before reaching the surface in a deeply alluviated area. It is thus evident that the height of the scarp is no measure of the net slip on the fault plane below the zone of weathered rock.

Normal faults are recognized by steep scarps and grabens, reverse faults by mole-track scarps and sinuous traces, and lateral faults by en echelon fault ruptures and associated tension ruptures differently oriented in right- and left-lateral movements.

NAME CLINOZOISITE SHOULD BE DROPPED

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Twelve specimens of the monoclinic epidote group ranging in composition from 4.9 to 15.3 per cent Fe_2O_3 were studied by optical, single-crystal X-ray, and powder-diffraction methods. Optical investigation showed that three of the low-iron monoclinic samples called clinozoisite exhibited both positive and negative signs in one specimen, and one sample containing more ferric iron than another with a negative sign was optically positive. Thus optic sign would not give an unambiguous basis for distinctions within a series based on increasing ferric iron.

The X-ray-diffraction work showed a continuous increase in unit-cell size with increasing ferric-iron content but no discontinuity in the variation of a_0, b_0, c_0, or β angle which could be designated as the boundary between clinozoisite and epidote. All 12 were $P2_{1/m}$. Weinschenk's original term clinozoisite was intended for a monoclinic mineral having a chemical composition identical with zoisite. The author also analyzed 27 zoisites (orthorhombic) and found no overlap in ferric-iron content with the 12 monoclinic samples. Thus there is no structural, optical, or chemical basis for distinguishing clinozoisite as a mineral distinct from epidote, and the name should be dropped from our overcrowded nomenclature.

STRATIGRAPHIC SECTION AND FUSULINIDS OF THE BIRD SPRING FORMATION NEAR LEE CANYON, CLARK COUNTY, NEVADA

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The thick section of the Bird Spring formation near Lee Canyon, Clark County, Nevada, consists of more than 7000 feet of predominantly carbonate beds that show no apparent major lithologic breaks. Megafossils collected from the basal 500 feet indicate that the lower 100 feet is Chesterian in age and that the Mississippian–Pennsylvanian boundary occurs within a transitional interval. Fusulinids collected from the remaining 6500 feet of the formation indicate that all the following divisions of the Pennsylvanian and Permian are represented: Morrowan, Atokan, Desmoinesian, Missourian, Virgilian, Wolfcampian, and Leonardian. The Pennsylvanian–Permian boundary is also gradational. A total of 2600 feet of Chesterian and Pennsylvanian beds and 4500 feet of Permian is present. Lack of important lithologic breaks and presence of all major fusulinid zones indicate that deposition of the predominantly carbonate Bird Spring formation was continuous from Late Mississippian, through the entire Pennsylvanian, and into at least the Leonardian of the Permian period. The upper limits of the Bird Spring formation could not be determined because of truncation by faulting.

PRECAMBRIAN ROCKS OF THE EASTERN UINTA MOUNTAINS, UTAH-COLORADO: A NEW CONCEPT

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Since the pioneer geologic surveys of the 1870's, the Precambrian rocks of the eastern Uinta Mountains have been divided into the "older" Red Creek quartzite and the "younger" Uinta Mountain group. Major John Wesley Powell considered the contact of these to be a profound unconformity, and more recent work of the U.S. Geological Survey maps the contact as a fault in some places and an unconformity in others.

The writer's regional studies and field examination of four key localities—Dutch John Mountain, Red Creek (Powell type locality), Jesse Ewing Canyon, and Beaver Creek—indicate that the Red Creek consists of variably altered and metamorphosed and completely reconstituted rocks equivalent to and derived from Uinta Mountain group sediments. The contact is a "melt" or diffusion boundary,

well defined in some places but elsewhere gradational across a zone 100 feet or more in width. The fault relationship exists to a limited extent only where late Tertiary normal faults have juxtaposed the metamorphic complex and the Uinta Mountain group.

The Red Creek is an extensive metamorphic aureole around the periphery of a deep-seated source of heat, possibly an unexposed batholith. The time of "emplacement" of the Red Creek complex is bracketed by other structural and stratigraphic events in the region as most likely between medial Eocene and medial Miocene.

The metamorphic relationship explains many heretofore puzzling and all but insoluble structural and stratigraphic problems in the eastern Uinta Mountain area.

ORIGIN OF DEVILS TOWER, WYOMING

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Devils Tower, in Devils Tower National Monument in northeastern Wyoming, is a nearly vertical outcrop of nepheline syenite porphyry about 800 feet in diameter and 600 feet high. The magma that cooled to form the Tower was intruded in Late Cretaceous or early Tertiary time into a series of sedimentary rocks of Permian, Triassic, Jurassic, and Early Cretaceous age. After it cooled, columnar jointing took place. To account for the attitude of the columnar jointing, which ranges from vertical to almost horizontal, it is deduced that the original intrusive body was tear-drop shaped with the more pointed end down. The striking appearance of Devils Tower today is the result of the jointing and subsequent erosion, which removed the relatively soft overlying and surrounding sedimentary rocks and the outer layers of igneous rock.

SOME PROBLEMS OF THE LAKOTA OF THE NORTHEASTERN BLACK HILLS

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The Lakota formation of the Black Hills was redefined recently by Waagé (1959, U. S. Geol. Survey Bull. 1081-B) as comprising the beds below a transgressive disconformity within the Inyan Kara group of the Lower Cretaceous and above the Morrison. This disconformity marks the contact with the Fall River above. Waagé recognized that the lower contact, although indefinite, lies somewhere between the dinosaur-bearing Morrison and the plant-bearing Lakota.

In the Northeastern Black Hills I have regarded the base of the Lakota as the base of the first massive sandstone above gray-green, calcareous claystone containing many dinosaur bones and nodules of spotted chert.

A composite, reference section of Lakota just southwest of Whitewood, South Dakota, comprises six members. Members 1, 3, and 5 are massive sandstones of different and variable thicknesses. Member 2 is an ostracode-bearing claystone containing limestone layers and nodules.

The fourth member comprises gray-white, silicified siltstone and sandstone containing polished pebbles and cobbles of chert bearing Upper Paleozoic fossils, quartzite, quartz, and chert-pebble conglomerate. The source of the pebbles was foreign to the Black Hills. Member 4 is characterized by much secondary chalcedony and hematite.

Considerable evidence of disconformity within member 4 exists.

The base of member 5 is the principal zone of fossil wood in the Lakota. Much of the white siltstone and fine sandstone in members 4 and 5 appears to contain volcanic ash.

Eighteen composite stratigraphic sections along 60 miles of outcrop indicate a persistence of the five members.

MINERALOGY OF THE PIERRE SHALE (UPPER CRETACEOUS) IN SOUTH DAKOTA AND ADJACENT AREAS

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Along the Missouri River the Pierre shale consists of clayey rocks with a carbonate-rich unit in the upper part and several thin marl beds in the lower part. Composition in the Black Hills area is similar except for larger amounts of silt and fine sand and absence of highly calcareous units. The shale commonly contains 65–80 per cent clay minerals, 15–25 per cent quartz, a few per cent feldspar, and small amounts of calcite, dolomite, biotite, pyrite, gypsum, jarosite, clinoptilolite, and organic matter. Cristobalite is abundant in many but not all siliceous shales. Typically, the clay-mineral fraction contains about 5 per cent each of kaolinite and chlorite, 15 per cent illite, 35 per cent montmorillonite, and 40 per cent mixed-layer illite-montmorillonite. Principal variations from this average composition are: (1) a more montmorillonitic phase that comprises the frothy-weathering units, and (2) a montmorillonite-poor phase, commonly with unusually large amounts of kaolinite and no chlorite, mainly in the lower part of the Pierre shale. Almost all bentonite beds of the Pierre are composed largely or exclusively of montmorillonite, rarely a little kaolinite, variable but usually small amounts of feldspar and biotite, and little or no quartz; the most abundant mineral in a few bentonite beds near the base of the Pierre shale is clinoptilolite. Differences in the mineral assemblages provide a supplemental basis for correlation of some of the Pierre units.

STRUCTURAL DAMAGE: 1959 HEBGEN LAKE EARTHQUAKE

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While geologic and seismographic evidences of a large shock were apparent, the damage to man-made structures was remarkably small. A number of log cabins as well as unreinforced hollow-unit masonry structures were within yards of the fault scarps, and these buildings in general were not severely damaged when not directly astride the scarp. Buildings across the fault were, of course, ruined. Bridges located in poor-ground areas swung back and forth. In one case the bridge swung at least 15 inches, and this violent motion damaged the reinforced concrete supporting beams. As has been noted in epicentral regions of other shocks, good construction and good foundation material are more important than distance from a fault.

In comparison with the 1952 Kern County (California) earthquake and with the 1933 Long Beach (California) earthquake, the building damage in the 1959 Hebgen Lake (Montana) shock indicates a different type of ground motion. The type of faulting and the focal depth are two suggested explanations. The need of a vastly increased network of strong-motion seismic instruments is apparent.

GROUND-WATER PHENOMENA ASSOCIATED WITH THE HEBGEN LAKE, MONTANA, EARTHQUAKE OF AUGUST 17, 1959

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The effects of the Hebgen Lake earthquake were both spectacular and widespread. The main fault movement took place along the north and east sides of a structural valley now occupied by the flat to gently sloping West Yellowstone plain. This plain is a water-rich area of numerous spring-fed streams and abundant ground-water resources. Most of the springs, some of them large, are associated with the volcanic rocks bordering the plain on the south, east, and northeast. In general the water level under the plain is shallow, and some large springs issued from the alluvium.

The earthquake had great effects on the ground- and surface-water regimen of the West Yellowstone area. All springs associated with volcanic rocks and all the streams into which they flowed became extremely turbid. The turbidity was caused by very fine material, some of which was colloidal. The flow of some springs increased greatly; other springs ceased flowing for several days. Some new springs emerged from fault scarps; these contained considerable radon.

Sand spouts, or earthquake fountains, were numerous. Ground water under considerable hydrostatic pressure built craters of well-sorted sand. In some places the craters were aligned along cracks, but in some places discrete craters were formed. Water containing fine sand issued under considerable pressure from two wells in the area.

Marked fluctuations of water levels were noted in observation wells as distant as Hawaii and Puerto Rico. The largest fluctuation recorded was more than 10 feet in an artesian well in Idaho.

TUNNELING IN PIERRE SHALE AT OAHE DAM, PIERRE, SOUTH DAKOTA

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By the time Oahe Dam is completed, approximately 8 miles of large-diameter tunnels will have been driven through the Pierre shale formation.

The Pierre formation is a compaction clay-shale derived from the consolidation of clays and silts of Cretaceous age. It is interstratified with closely spaced bentonite seams and at the damsite it is highly faulted.

Tunneling work at Oahe Dam was accomplished under four major contracts, by use of a continuous miner designed specifically for the work. The original machine was known as the "Mittry Mole", and modified models were used on the remaining contracts. Average rates of progress were from 40 to 50 linear feet of full bore per day, with maximum rates of 100 to 135 feet.

Principal mining problems were due to shale fallouts which often stopped the machine. Fallouts occurred when the tunnel bore encountered faults and fault intersections particularly at elevations above the crown and in areas adjacent to the tunnel spring line. When these fallouts were not controlled immediately they often extended several tens of feet above and beyond the tunnel periphery causing large blocks of shale to fall and stop the machine. Time was the important factor in controlling the shale fallouts. Several methods are used to support the roof in fallout areas.

A unique method was used to map the geologic features.

LATE PLEISTOCENE HISTORY OF BEAR LAKE VALLEY, UTAH-IDAHO

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Bear Lake Valley, Utah-Idaho, is 45 miles long but not more than 8 miles wide and lies between the Bear River Range on the west and the Bear Lake Plateau and the Preuss Range on the east. Bear Lake occupies the southern half of the valley at present, with a high-water level of 5923 feet, but the whole valley floor was occupied by a lake in late Pleistocene time. Three early stages of the lake have been recognized, and their shore-line features mapped, at elevations 5948 feet, 5938 feet, and 5929 feet.

Bear River enters the valley on its eastern side and leaves at the northern end. It appears to have been superposed on the older structures of the area from a cover of Pliocene sediments. It has been reasoned that the expanded Pleistocene lake required damming of some sort in the narrows at the north end of the valley. Alluvial-fan debris of a relatively dry interglacial age has been proposed as the agent. Ice damming has also been suggested. The evidences of recent diastrophism in the valley offer another explanation which may well be the most satisfactory. Fault scarplets are traceable along the eastern side of the valley from Dingle to the southern end of the lake and displace the deltas at Indian Canyon and both of the Eden canyons. Fathograms of the lake bottom show similar scarplets associated with faults in the most recently deposited bottom sediments.

STRATIGRAPHY OF THE INYAN KARA GROUP IN THE SOUTHERN BLACK HILLS, SOUTH DAKOTA AND WYOMING

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The Inyan Kara group, which consists of the nonmarine Lakota and Fall River formations of Early Cretaceous age, unconformably overlies strata of Late Jurassic age and is conformably overlain by the marine Skull Creek shale of Early Cretaceous age. The group is about 325 to 700 feet thick.

The Lakota formation, the basal formation of the Inyan Kara group, is composed of three members (in ascending order): an unnamed member, the Minnewaste limestone, and the Fuson member. The unnamed member consists of two fluvial sandstone units and fine-grained stratigraphic equivalents, the older of which is characterized by abundant carbonaceous material. The Minnewaste limestone member, restricted to the southeastern Black Hills, is a lacustrine sandy limestone. The Fuson member includes two fluvial sandstone units separated by variegated mudstone. The sandstone is locally conglomeratic, and the mudstone contains polished siliceous pebbles and some sandstone lenses.

The Fall River formation, which unconformably overlies the Lakota formation, consists of three units: (1) a lower unit of interbedded carbonaceous siltstone and sandstone; (2) a middle unit of fluvial sandstone and fine-grained stratigraphic equivalents; and (3) an upper unit of interbedded mudstone, siltstone, and sandstone.

Cross-bedding and the orientation of the fluvial sandstones of the Inyan Kara group indicate that the source of the sediments was to the east and southeast, probably eastern South Dakota and Nebraska. Gentle warping, which may represent the beginning of the uplift of the Black Hills, probably localized the deposition of the fluvial sandstones.

ABSTRACTS OF PAPERS SUBMITTED FOR THE MEETING IN VANCOUVER, BRITISH COLUMBIA, MAY 5–9, 1960

CORDILLERAN SECTION (GSA), PACIFIC COAST SECTION (PS), AND SEISMOLOGICAL SOCIETY OF AMERICA

GROUND-MOTION MEASUREMENTS ON UNDERGROUND NUCLEAR DETONATIONS

W. M. Adams, P. L. Flanders, W. R. Perret, R. G. Preston, and D. C. Sachs
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Subsurface and surface-motion measurements were made on six underground nuclear detonations in the Oak Spring tuff at Nevada Test Site in Operation Hardtack II: shots Mars (13 tons), Tamalpais (72 tons), Neptune (90 tons), Logan (5 kt), Evans (55 tons), and Blanca (19 kt). Free-field peak radial accelerations decreased as the inverse third or fourth power of the slant range, as for the Rainier shot. Particle velocities attenuate at a rate between the inverse square and inverse cube. Maximum radial and tangential subsurface stress varied as the inverse cube of radial range. Observed peak strain suggests attenuation at a rate between inverse cube and inverse square of range. Maximum upheaval at Blanca surface zero was about 25.5 feet; at 750 feet it was 2.5 feet, and at 910 feet it was 1.5 feet. Reed gage spectra indicated a shift of maximum energy to lower frequency with increasing ground range. Vertical, radial, and transverse components of peak-surface acceleration followed an empirical equation of the form

$$A(g) = 3.2 \times 10^6 \, W^{0.7}(\text{kt}) \, R^{-2}(\text{ft}).$$

Components of peak-surface displacements followed individual relationships. Displacement is more precisely predicted than is acceleration. The tuff has a velocity of 6200 feet per second, the underlying dolomite 11,700 feet per second. The crust at NTS has a velocity of 6.58 km per second and a thickness of approximately 30 km. The top of the mantle has a velocity of 8.08 km per second and dips eastward.

USE OF LONG-PERIOD SURFACE WAVES FOR THE STUDY OF EARTHQUAKE MECHANISM

Keiiti Aki

Rayleigh and Love waves are used for the study of the earthquake mechanism by the method of phase equalization.

A comparative study of Love waves from California shocks with those from Nevada shocks strongly supports the hypothesis of a pair of couples for the earthquake source rather than a single couple.

Source motions of California shocks are derived from Rayleigh waves recorded at stations in the east by the equalization of phase delay caused by propagation and recording. It was found that the sense of the source motion thus derived is in agreement with the fault-plane solution obtained from the *P*-wave data.

Source motions of 53 circum-Pacific shocks are derived from Pasadena records of mantle Rayleigh waves. The shape of the source motion is interpreted, under reasonable assumptions, in terms of the direction of the force at the source. The direction of the force shows a systematic distribution which favors the hypothesis that right-hand strike slips prevail throughout the circum-Pacific earthquake belt.

GEOLOGY OF PROPOSED COLUMBIA RIVER DAM SITES, BRITISH COLUMBIA*

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Geological field examinations of 20 proposed dam sites were made. Most of the sites were drilled, and the holes logged by geologists. The geology of the 10 most important sites will be discussed briefly. The suitability of each site for dam abutments, spillways, and availability of materials will be referred to. Adverse geological conditions at some of the sites, which must be taken into account in future engineering and construction, will be described. The more important of these are: (1) buried river channels; (2) extensive faulting, shearing, and jointing; (3) slide areas; (4) abundance of schist; (5) abundance of limestone; (6) shortage of nearby materials for fill, aggregate, and riprap; and (7) thick deposits of permeable unconsolidated materials. Some sites have more adverse geological factors than others, and none has all those listed.

NEW INTERPRETATION OF RELATIONSHIPS OF PLIOCENE SEDIMENTS TO ADJACENT FORMATIONS, STANISLAUS COUNTY, CALIFORNIA

Charles F. Bacon
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Nonmarine lower and middle Pliocene rocks in Stanislaus County along the western edge of the San Joaquin Valley are exposed in a comparatively narrow belt extending from south of Tracy to a point near Newman, California. They rest in conformable and gradational contact upon the Neroly formation of Mio-Pliocene age and are unconformably overlain by nonmarine sediments considered equivalent to the Tulare formation of Plio-Pleistocene age.

The entire sequence of Pliocene and Pleistocene rocks above the Neroly formation has been questionably referred to the Tulare formation, but detailed mapping indicates that older Pliocene beds can be separated from the younger ones as follows: (1) dip variation often is in excess of 10° in the older beds, (2) lithologic variations only in the younger beds, (3) fossil evidence, (4) previous similar interpretation of an almost identical situation in an area separated to the south, and (5) older beds are missing to the north.

Studies of the two units with regard to engineering properties indicate that certain phases of the younger beds have lower slope-stability characteristics than any commonly found in the older beds and that the older beds are superior as a source of dependable borrow material. The younger unit contains more expanding clays than the older with the possible exception of reworked or residual material.

FRANCISCAN FORMATION OF CALIFORNIA AS AN EXAMPLE OF EUGEOSYNCLINAL DEPOSITION

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Rocks assigned to the Franciscan formation range in age from Late Jurassic to Late Cretaceous and extend through the western part of California from the northern boundary southward for more than 500 miles to Santa Catalina Island. Its marginal position and the presence of serpentinites suggest that the eugeosyncline should be classed as ensimatic. The formation is at least 25,000 feet thick and may be much thicker. No lower contact has been recognized; what underlies it can only be inferred.

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Rock types and estimated percentages are: graywacke (80), siltstone and shale (10), conglomerate (<1), limestone (<1), mafic volcanic rocks (8), chert and accompanying shale (<1), glaucophane and related schist (<1).

Graywacke is characterized by beds half an inch to tens of feet thick; absence of current or sorting features except in supposed lowest and highest parts; widespread shale fragments; local carbonized wood fragments; variable composition with feldspar ⅓–⅔, quartz 1/10–½, mafic volcanic rocks 0–⅓; matrix 1/20–⅓, with finest fraction consisting of mica >⅓, kaolinite up to ⅓, chlorite <⅓; highly angular to subangular grains; poor sorting.

Siltstone and shale, generally in thin interbeds with graywacke, are compositionally like the graywacke but finer-grained. Conglomerate is rare through the entire section. Beds are generally thin, but some are hundreds of feet thick. Clasts include both Franciscan and non-Franciscan types. Limestone, in thin beds of restricted distribution, is chemically precipitated and generally includes lenses of chert.

Mafic volcanic rocks are chiefly altered submarine eruptive rocks occurring as pillow lavas, breccias, and tuffs. Included are low-olivine basalt, spilite, and rarer quartz keratophyre. Chert, generally rhythmically bedded with distinctive iron-rich shale, is related spatially and probably genetically to volcanic rocks.

Most of the Franciscan formation is not metamorphosed; however, local areas contain laumontite, or jadeite, or glaucophane and associated minerals.

The rocks have been so folded, shattered, and sheared that nearly every outcrop presents some structural complexity, yet lithic units have mappable continuity. The gross structures seem to consist of open folds cut by strike-slip faults which nearly parallel fold axes. Major faults form wide zones containing blocks of competent rocks in a more highly sheared groundmass of less competent rocks.

SELECTIVE STAINING OF PLAGIOCLASE AND K FELDSPAR ON ROCK SLABS AND THIN SECTIONS

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Plagioclases, other than pure Na feldspar, may be stained an intense red after etching with hydrofluoric acid by dipping in barium-chloride solution, rinsing, and treating with a solution of potassium rhodizonate. Barium ion replaces calcium ion freed by etching the plagioclase and forms insoluble red barium rhodizonate.

Plagioclase can be stained red, and on the same surface K feldspar stained yellow by combining this procedure with the well-known cobaltinitrite method of staining K feldspar. If the K feldspar contains appreciable plagioclase, as in cryptoperthite, it is stained an intermediate orange color; coarser perthite may show individually stained lamellae.

Many applications of the technique are apparent. On stained slabs of granitic rocks the commonly obscure interrelations of the light-colored minerals—quartz and feldspars—are strikingly revealed, as are many fine details not otherwise readily observed. Modal analyses may be made more rapidly and probably more accurately on stained slabs or sections. The brilliant color contrasts make the stained slabs especially effective for student instruction.

FORAMINIFERAL ECOLOGY OF THE GULF OF CALIFORNIA

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The Gulf of California is about 700 miles long, 100 miles wide, and more than 3000 m deep. Deep basins within the Gulf provide a highly diversified framework for the evaluation of biofacies patterns.

General faunal trends include the following: maximum species diversity and foraminiferal numbers occur on the outer shelf and upper slope; benthonic and planktonic Foraminifera are more abundant than diatoms and radiolarians on the continental shelf and in the upper bathyal zone; radiolarians and diatoms are most abundant in the sediments of basin bottoms; radiolarians are relatively more abundant than diatoms and Foraminifera in the deepest basins; porcellaneous Foraminifera constitute more than 20 per cent of the benthonic specimens of the inner shelf; malformed Foraminifera are most common in inshore waters; and dwarfism appears to be most common near the environmental limits of species.

Highly generalized dominant faunas are:

Environments	*Faunas* (Depths in meters)
Lagoonal	*Elphidium mexicanum*
	Quinqueloculina spp.
	Streblus tepidus
Beach	*Buccella tenerrima*
	Cibicides fletcheri
	Elphidium crispum
	Miliolids
	Rotorbinella loamensis
Inner Shelf	0–37
	Buccella mansfieldi
	Buliminella elegantissima
	Hanzawaia nitidula
	Nonionella basispinata
Outer Shelf	37–152
	Bolivina interjuncta
	Bulimina denudata
	Cassidulina laevigata
	C. minuta
	Epistominella bradyana
Upper Bathyal	152–610
	Bolivina plicata
	Bolivina seminuda
	Bulimina exilis tenuata
	Cassidulina delicata
	C. cushmani
Upper Middle Bathyal	610–1524
	Bolivina argentea
	Bolivinita minuta
	Bulimina striata mexicana
	Epistominella smithi
	Pseudoeponides tener
	Valvulineria araucana
Lower Middle Bathyal	1524–2438
	Eponides tumidulus
	Nonion barleeanus
	Uvigerina proboscidea
	Virgulina spinosa
Lower Bathyal	Deeper than 2438
	Bulimina rostrata
	Nonion pompilioides
	Uvigerina senticosa

LATE MESOZOIC SEQUENCES IN THE NORTHEASTERN CASCADE MOUNTAINS OF WASHINGTON

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Volcanic and sedimentary beds of the Upper Newby formation, northeastern Cascade Mountains of Washington, were previously assigned a "Triassic-Jurassic(?)" age. These strata have since been traced northward into marine beds of the same lithology containing fossils indicative of Neocomian (early Cretaceous) age.

A thick succession of marine plagioclase arkose, black siltstone, and shale and granitic boulder conglomerate rests with angular unconformity on the upper Newby. These beds which have an exposed thickness exceeding 10,000 feet are believed to be equivalent in part to the Ashcroft, British Columbia, Jackass Mountain "group" of probable Albian age.

The Virginian Ridge formation, dominantly black siltstone with intercalated chert grain sandstones and chert pebble conglomerates, is markedly discordant on the Newby and on the Jackass Mountain equivalent in some areas and disconformable on the latter in others. Its marine fossils have been variously dated as "Upper Albian-Cenomanian" or "Santonian-Campanian". The Winthrop arkose, conformable on the Virginian Ridge and only a few hundred feet thick in the Twisp River area, thickens to the north where it is correlated with "Division B and C" (14,000 ± feet) of the "Pasayten group" of Rice (1949). Conformable over the Winthrop is the red-bed Ventura formation of Russell (1898), equivalent in part to "Division D" of Rice's "Pasayten". The Ventura grades upward into the Midnight Peak andesitic sediments, breccias, and flows which may be equivalent in part to the Kingsvale "group".

Probable latest Cretaceous and/or earliest Tertiary deposition is represented by the Pipestone formation.

OBSERVATIONS OF THE LAMB-PEKERIS GROUND-RESPONSE PATTERN IN THE YELLOWSTONE EARTHQUAKE OF AUGUST 18, 1959

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Two seismograms of the Yellowstone earthquake of August 18, 1959, made with the Isabella fused-quartz extensometer exhibit very nearly the ground-response pattern first predicted by Lamb (1904) for an impulse source, as modified by Pekeris (1955) to correspond with a step source. In one of the seismograms the extensometer-output voltage which is proportional to ground strain was modified by a single-stage integrating network connected ahead of the recorder. This produced a response equivalent to a pendulum of 1000 seconds period. The other seismogram was recorded with a double-integrating network. Previous failures to record this pattern were due to insensitivity of existing instruments to the long-period waves involved relative to their response to the shorter-period vibratory movements of the ground resulting from the layered structure of the earth and the variation of wave speed with depth.

MODE OF DEPOSITION OF LUDWIGITE, KOTOITE, AND CUBANITE IN DUNITE ON JUMBO MOUNTAIN, SNOHOMISH COUNTY, WASHINGTON

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Rocks of early Tertiary age have been intruded by discontinuous sills or dikes of dunite, part of a belt of ultramafic intrusions that extends several miles southeastward to the Sultan Basin and the

Mackinaw mine. Both metasedimentary and ultramafic rocks were intruded by a quartz diorite stock from which boron-bearing fluids rose along small faults or shear zones, particularly in the dunite about 750 feet from the quartz diorite contact.

Introduction of boron and iron in at least two places, one 3000 feet northwest of Jumbo and the other 2000 feet south, under pneumatolytic conditions resulted in deposition, by replacement of the dunite, of considerable dark, blackish-green, silky, apparently iron-rich ludwigite (essentially opaque in the finest fibers). The kotoite, its precise location not yet determined, seems to have followed deposition of magnesium-rich ludwigite which in turn followed iron-rich ludwigite, indicating progressive impoverishment of iron locally in the gaseous emanations. In a few specimens ludwigite encloses magnetite, grains that probably are sulfides of nickel, and nickelian pyrrhotite.

Cubanite, which encloses other minerals not yet positively identified, is associated with chlorite (sheridanite) but not ludwigite and is apparently a few hundred feet nearer the quartz diorite contact than the two occurrences of ludwigite.

SEISMIC STUDIES OF CRUSTAL STRUCTURE IN THE EASTERN BASIN AND RANGE PROVINCE, PART II

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Results are presented from a continuation of the seismic studies of quarry blasts at Promontory and Lakeside, Utah.

Measurements were made of seismic energy at distances of 201.4 km and 243.7 km from a quarry blast at Lakeside, Utah, on February 8, 1959. Assuming the time–distance plot for the Promontory explosions (Berg and others, 1959) the energy traveling in the material characterized by a velocity of approximately 7.59 km/sec was first to arrive at these distances. The wave paths for the first arrivals passed beneath the Wasatch Mountains in the 7.59 km/sec medium for the station located at 201.4 km and beneath the Wasatch and Uinta mountains in the 7.59 km/sec medium for the station located at 243.7 km. After the data were corrected for elevations, observed delays were 0.11 second at 201.4 km for energy traveling beneath the Wasatch Mountains and 0.27 second for energy traveling beneath the Wasatch and Uinta mountains. Downwarpings of the surface of the 7.59 km/sec material were computed to be 1.3 km for the 0.11-second delay (probably within experimental error) and 3.1 km for the 0.27-second delay. More accurate velocity control for the elevation correction at 243.7 km could possibly change the time delay of 0.27 second.

A composite time–distance plot of seismic arrivals to a distance of approximately 1010 km from explosions at Promontory and Lakeside, Utah, shows that the first arrivals of seismic energy from these sources travel with velocities of 5.7 km/sec to a horizontal distance of approximately 80 km, 6.3 km/sec from 80 to 130 km, 7.6 km/sec from 130 to 630 km, and 8.0 km/sec from 630 to 1010 km. Assuming flat-lying beds and constant velocities, the data are interpreted to indicate three velocity discontinuities at depths of 9 km, 25 km, and 72 km, respectively. Additional data are needed to substantiate the existence of the 8.0 km/sec medium beneath the eastern Basin and Range province.

CORDILLERAN FUSULINID ZONATIONS

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One-quarter century has elapsed since pioneer studies by Longwell and Dunbar in southern Nevada and by Thompson and Bissell in central Utah demonstrated utilitarian value of fusulinids in zonation of Pennsylvanian and Permian Cordilleran miogeosynclinal strata. Subsequent studies permit the present synthesis.

Strata of Late Chesteran age contain the Foraminifera *Endothyra*, *Paramillerella*, and locally

Millerella. Springeran rocks contain advanced species of these same genera. Morrowan strata have *Paramillerella* and *Millerella*, in association with *Nankinella* and *Pseudostaffella*. The genus *Profusulinella* typifies lower Derryan, and *Fusulinella* occurs in upper Derryan; *Eoschubertella* ranges throughout this series in some sections. The zone of *Fusulina* is valid for Desmoinesian rocks; *Wedekindellina* is found low in this series. *Triticites* characterizes Missourian rocks but does range through Virgilian and into Permian. *Kansanella* is found in upper Missourian. Virgilian strata contain advanced *Triticites* and *Waeringella*.

Rocks of Wolfcampian age are typified by presence of *Dunbarinella*, *Oketaella*, *Schwagerina*, *Pseudoschwagerina*, *Pseudofusulina*, and *Pseudofusulinella*; subzones contain certain genera only. *Bartramella* ranges from lower Desmoinesian into Wolfcampian. *Parafusulina* is abundant in Leonardian strata; advanced *Schwagerina* also occurs, and *Schubertella* can be found. Advanced forms of *Parafusulina* indicate presence of Guadalupean rocks; forms referred with query to *Leëlla* have been observed in Guadalupean series.

Subzones can be defined. Range zones have been established for numerous species. Spectacular success is achieved with rocks of Derryan and younger ages; some subzones contain certain genera, but most are defined by species having relatively wide distribution and limited stratigraphic range.

BEHAVIOR OF WINDOW PANELS UNDER LATERAL FORCES

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The program reported in this paper was performed to investigate the ultimate in-plane deflection of fenestrated walls subjected to lateral forces.

Although it is apparently the intention of the California State Administrative Code, Section 111(b) of Title 21, to eliminate the possibility of glass breakage because of wind or seismic forces, no supporting test data were available.

Thirty-nine glazed window panels were tested under a horizontal in-plane racking force applied to the horizontal top member of a steel pin-connected, or hinged, loading frame, holding these panels. The following variables were included: panel size and panel configuration, panel attachment to hinged frame, sash material, clearance between glass and sash, and hardness of putty.

The ultimate in-plane deflections from head to sill under a racking load were determined theoretically for single-panel metal-sash windows glazed with soft as well as hard putty, and were in good agreement with the experimental results. Also for multiple-panel metal-sash windows glazed with soft putty, the calculated deflections were in good agreement with the test results.

HYPOCENTER LOCATION OF EARTHQUAKES BY COMPUTER METHODS

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A method for locating hypocenters using an IBM 60 digital computer has been developed. In its most general form it is a simultaneous solution of equations of the form:

$$H + \frac{\partial T}{\partial \Delta} \cdot \frac{\partial \Delta}{\partial \lambda} + \frac{\partial T}{\partial \Delta} \cdot \frac{\partial \Delta}{\partial \phi} + \frac{\partial T}{\partial h} = A - C$$

where H is the origin time; A is the arrival time (recorded); and C is the arrival time (computed).

It was found that a very slight inaccuracy in the data and the vagaries of the average travel-time curves when applied to specific paths resulted in incorrect depth determinations. Therefore, various modifications have been made to permit the computer to discover and reject the data for extreme deviations and to allow it to test for depth by methods that depend on variations in epicentral distances to the several stations used in the computation.

TRIASSIC AND JURASSIC ROCKS OF THE QUEEN CHARLOTTE ISLANDS

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Triassic and Jurassic rocks of the Queen Charlotte Islands, British Columbia, are typical of those of the northern Pacific coast but are better preserved and exposed than in most areas. The oldest rocks are featureless greenstones more than 6000 feet thick, overlain conformably by Karnian and Norian marine sedimentary rocks. The latter consist of massive gray clastic limestone 200 to 650 feet thick, overlain by 400 to 800 feet of thin-bedded black limestone, and in turn overlain by about 1900 feet of thin-bedded black limy argillite and argillaceous limestone. The Triassic rocks were folded and beveled prior to the deposition of 2000 to 3000 feet of Toarcian conglomerates, brownish graywackes, and gray shales. These lower Jurassic rocks have been called the Maude formation on Skidegate Inlet. Overlying the Maude is a volcanic sequence characterized by fragmental rocks. Of three intergrading facies, one is composed of andesitic pillow lavas and aphanitic fragment agglomerates and is 7000 to 10,000 feet thick, another of ignimbrites at least 5000 feet thick, and a third of porphyry fragment agglomerate, andesite porphyry flows, and volcanic sedimentary rocks 7000 feet thick. Rocks of the latter facies on Skidegate Inlet have been called the Yakoun formation and range in age from Bajocian to Callovian.

TYPES OF DEPOSITION ON ALLUVIAL FANS IN WESTERN FRESNO COUNTY, CALIFORNIA

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Deposition on alluvial fans in western Fresno County is caused by widening of a flow as it spreads out on the fan. The widening is accompanied by a decrease in depth and velocity, thus causing sediment to be deposited.

The deposits may be mudflows, water-laid sediments, or a type intermediate between mudflow and water-laid sediments. Depositional characteristics and grain-size analyses of 102 samples provide some defining properties for these three general classifications. Only 12 of the 277 sorting indices are outside the limits set for the depositional types. The three sorting indices used were the Trask sorting index, *So*; the quartile deviation, $QD\phi$; and the standard deviation, $^{\sigma}\phi$.

Most of the samples contain shale fragments and a montmorillonite-type clay, in addition to quartz, feldspar, and other rock and mineral fragments. The quantitative properties listed in the table may be different for deposits that have different source rocks.

Water-Laid Sediments	Intermediate Deposits	Mudflow Deposits
	Depositional Characteristics	
No discernible margins; usually clean sand or silt; cross-bedded, laminated, or massive	No sharply defined margins; clay films around sand grains and lining voids; graded bedding and oriented fragments	Abrupt, well-defined margins, lobate tongues; clay may partly fill intergranular voids. May not have graded bedding or particle orientation
	Average Parameters from Grain-Size Analyses	
Clay content is 6 per cent, *So* is 1.8, $QD\phi$ is 0.8, $^{\sigma}\phi$ is 1.4.	Clay content is 17 per cent, *So* is 4.0, $QD\phi$ is 2.0, $^{\sigma}\phi$ is 3.9.	Clay content is 31 per cent, *So* is 9.7, $QD\phi$ is 3.1, $^{\sigma}\phi$ is 4.7.

PILLOW BRECCIAS IN THE VANCOUVER VOLCANIC ROCKS AND THEIR ORIGIN

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Isolated-pillow breccias and broken-pillow breccias on Quadra Island, British Columbia, are neither flow breccias nor pyroclastic rocks in the usual sense, but have characteristics both of turbidites and of ignimbrites.

In several typical successions ordinary close-packed pillows at the base rest upon basalt flows or upon bedded limestone. Matrix between pillows is less than 10 per cent of the rock. Gradationally upward the matrix increases to as much as 80 per cent, the pillows become isolated and diversiform, and small pillows become common. Some pillows are split. The matrix, mainly palagonitic crystal tuff with basaltic fragments, has a foliation resembling compact structure in ignimbrites. Above this in gradational contact is nonstratified breccia with similar matrix but with fragments of pillows broken after solidification. The proportion of broken pillows and of small clasts increases upward. Laminated tuff with load casts in its upper surface occurs within the broken-pillow breccia.

Close-packed pillows apparently accumulated in relatively clear water and reached their present position while plastic. Isolated pillows were buoyed up by increasingly turbid and vapor-charged water as tuffaceous debris, partly spalled from pillows partly pyroclastic, accumulated. Thickening of the water-pillow-tuff mass led to instability, subaqueous slumping, and fragmentation of solidified pillows.

Pillow breccias of this origin may occur more generally than has been realized. Similar rocks have been described from at least five localities elsewhere in the world. Others closely resembling isolated-pillow breccias have been called flow-top breccias.

ROCKFILL DAMS

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For the purpose of this discussion rockfill dams are defined as dumped and sluiced rock fill with slopes at approximately the angle of repose of the rock. The downstream slope is generally left as dumped and sluiced. The upstream slope is generally covered with impervious material with proper bedding and cover or filters, and the face which will be exposed to the reservoir is blanketed with rocks for stability and prevention of wave cutting.

Difficulties encountered during construction of certain rockfill dams in the States indicate that physical properties of the rock available for the fill have not been given enough consideration. The young science of Rock Mechanics has grown up in the mining and tunneling industry and has direct application to rockfill dam design, very much simplified and still an art, but applicable none the less. The most important physical properties of rock and tentative recommended values are as follows:

Compressive strength	Minimum	7500 psi
Absorption	Maximum	3 per cent
Specific gravity (Apparent)	Minimum	2.55
Seismic velocity	Minimum	5000 to 7500
Freeze–thaw test	Maximum	
	Loss 50 cycles	1.5 per cent
	Loss 100 cycles	5.0 per cent

If values of rock from a specific job approach these values, very serious study is indicated. The height of dam and allowable dumping height will be important if the available rock has compressive strength less than 10,000 psi.

EARTHQUAKE RECORDED BY LOW-COST INSTRUMENT

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As part of a current project to supplement the Coast and Geodetic Survey strong-motion seismograph network with low-cost instruments, the Survey seismoscopes were installed at Hollister, California, at the Almaden Winery on the San Andreas fault, and at the Westvaco Quarry west of the fault. The first sizable records were obtained from a magnitude 5 earthquake on January 19, 1960. Results are given in terms of maximum velocity obtained by the seismoscopes and are compared with the velocity spectrum computed from the Hollister accelerograph record.

RELATIONS OF MAJOR FOLDS AND REVERSE FAULTS IN SANTA LUCIA RANGE, CALIFORNIA

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Major Plio-Pleistocene folds and faults of the California Coast Ranges are displayed unusually clearly in the rugged country of Junipero Serra quadrangle. The area is significant because granitic and metamorphic rocks that here form the core of Santa Lucia Range were pressed into large anticlines and synclines before they rose vertically along high-angle reverse faults that cut these folds. The basement was folded so severely that its upper surface dips more than 45° in many places. The faults are spaced at intervals of half a mile to 3 miles and typically dip 60°–85° toward former anticlines. Thick sequences of Tertiary strata are preserved in major synclines that lie along the border of the basement core and are commonly overturned away from it. These sedimentary remnants indicate that the basement was overlain by 5000–15,000 feet of beds when folding started.

The core consists of a central granitic mass and a mantle of high-grade metamorphic rocks. Although these rocks are crushed here and there, their textures are deformed moderately if at all. Judged from a common parallelism between metamorphic foliations and the Plio-Pleistocene faults, the metamorphic structures may have guided the later deformations to a considerable degree. The close association of horizontal folds and steep reverse faults (rather than thrusts and tear faults) was possibly caused by a compression that acted on the intermediate part of the crust as well as on its upper part.

GEOLOGIC PROBLEMS AT THE GORGE HIGH DAM, SKAGIT RIVER, WASHINGTON

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Seattle City Light's Gorge High dam is located in the northern Cascades approximately 22 miles south of the Canadian border. At the site the river flowed parallel to and on a bedrock ridge separating deep buried channels on either side. The fill was composed predominantly of sand but contained lenses of gravel and scattered blocks and boulders.

Adverse geological features included artesian water issuing from drill holes in the gneissic bedrock ridge, a fault at the base of the right abutment, and loose joints in the near-vertical canyon walls above the deep excavation. The presence of a diversion dam 400 feet upstream from the site caused a high head for ground water close to zone of deep excavation. The limited space between the new and existing dam required upstream excavation slopes to be 1½:1 or steeper to provide room for diversion facilities. The safety of the existing dam providing 108,000 kw had to be insured.

The unique solution to this problem was a frozen, subsurface dam with a maximum height, in the left channel, of 220 feet. Brine was pumped through vertical drill holes spaced at 4 feet on centers.

Temperatures throughout the freeze curtain were measured by thermocouples. The freeze curtain has proved to be an effective cofferdam. The faulting was treated by cleaning and backfilling and a slight design change. The loosely jointed rocks were stabilized by pinning.

UPPER CRETACEOUS OF VANCOUVER, BRITISH COLUMBIA

C. H. Crickmay and S. A. Pocock

Sections of the Cretaceous system in Comox and Nanaimo areas, British Columbia, are reviewed and correlated. Correlations are carried, with the aid of plant megafossils and microfloral evidence, to several mainland areas, particularly the vicinity of the city of Vancouver. It is shown that the Capilano Creek beds and equivalents on the mainland are correlative with the lower formations of the Nanaimo series, whereas the Stanley Park and the Barnett beds are correlative with the upper formations at Nanaimo. Although long suspected, the older interpretations, with which these new conclusions are at variance, are now controverted mainly with the aid of detailed, quantitative microfloral evidence. Conclusions are that the Upper Cretaceous basin was of great breadth, extending widely over Vancouver Island and the Straits and thence eastward into what is now the Cascade Range. Various evidence is used to date the orogeny which finally disintegrated the Cretaceous basin.

PALEOZOIC EUGEOSYNCLINAL SEQUENCE OF SOUTHWESTERN BRITISH COLUMBIA AND NORTHWESTERN WASHINGTON

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Adjacent parts of southwestern British Columbia and northwestern Washington contain the only definitely identified Paleozoic rocks exposed along the Pacific Coast of North America between the Klamath Mountains of southwestern Oregon and the Alaska Panhandle. Units known to occur have ages including Middle Devonian, Early and Middle Pennsylvanian, Early Permian, and Middle and Late Permian. Rocks of the eugeosynclinal suite characterize the sequence.

The Middle Devonian consists of at least 1400 feet of spilitic volcanic rocks, graywacke, graywacke siltstone, argillite, breccia, conglomerate, ribbon chert, and reef-complex limestone. In the San Juan Islands these rocks appear to rest unconformably on an amphibolitic gneiss complex cut by dioritic rocks. The Lower and Middle Pennsylvanian consists of more than 3000 feet of argillite, shale, graywacke, volcanic rocks, chert, and limestone. It is geographically the most widespread sequence. Disconformably above the Pennsylvanian in several areas is 100–600+ feet of conglomerate and plant-bearing carbonaceous sandstone believed to represent continental deposition. At one locality this is overlain by Lower Permian limestone. The Lower Permian consists of at least 1000 feet of chert, graywacke, volcanic rocks, and fusulinid limestone. Middle and Upper Permian rocks include ribbon chert and volcanic rocks containing limestone lenses, breccias, argillite, and graywacke. The thickness is thought to be at least 10,000 feet. The limestone members contain a Tethyan fusulinid and algal fauna similar to that of the upper part of the Cache Creek group of interior British Columbia.

REVISION OF THE GEOLOGY OF THE SAN JUAN ISLANDS, WASHINGTON

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Recent studies of the geology of the San Juan Islands in northwestern Washington have necessitated the revision of at least four major units established by the pioneer work of McLellan in 1927.

The Orcas group, originally designated as Devono-Mississippian, is now known to contain rocks of Middle Devonian, Early and Middle Pennsylvanian, Middle and Late Permian, and Late Triassic age. No diagnostic Mississippian fossils have been found. The Leech River group, originally designated as Pennsylvanian–Permian, was found to include rocks of Early and Middle Pennsylvanian and Cretaceous age. Volcanic rocks originally described as intrusive dikes of the Eagle Cliff porphyrite appear to be composed largely of submarine pillow lavas of Permian and Cretaceous age. The Turtleback complex described as a variety of intrusive rocks, offshoots of a late Jurassic batholith located to the west on Vancouver Island, is now known to include many areas of an amphibolite gneiss complex intruded by dioritic rocks of pre-Devonian age. Granitic rocks thought to be of early Mesozoic or later age are also present. In addition the Turtleback contains volcanic and sedimentary rocks of Devonian, Early Permian, and Middle and Late Permian age. Large areas on the Islands contain sequences as yet unassigned to a definite place in the geological column.

EFFECT OF VARIATIONS IN CRUSTAL THICKNESS ON LOVE-WAVE DISPERSION

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Crustal structures obtained from Love-wave dispersion yield "average" thicknesses along the propagation paths. The validity of these results depends on the crust being uniform in thickness along the propagation paths. In many cases there are at least portions of the path in which this condition is not satisfied. An evaluation of the effect of thickness variations on both the group and phase velocities can be obtained by considering a crust whose thickness varies as a sine function of distance. The effect of any portion of a sinusoidal thickness variation can be considered. This provides a method for evaluating the effect of even rapid thickness variations as long as they can be approximated by a sine curve.

PETROLOGY OF JURASSIC MARINE TUFFS, CENTRAL OREGON

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Near Izee on South Fork of John Day River in Grant County, Oregon, approximately 17,500 feet of marine Jurassic sedimentary and pyroclastic strata is exposed in a steeply dipping homoclinal sequence. Original plagioclase in most beds has been partially or completely converted to epigenetic albite. Three homogeneous tuff units that display varying degrees of albitization and related alteration along their strike were studied by field and petrographic examinations, and 25 chemical analyses were made of samples collected from them.

In an acidic vitric-crystal tuff unit, albitization resulted from pronounced soda metasomatism accompanied by slight increase in silica, decrease in iron, strong dehydration, and drastic reduction in CaO, MgO, and K_2O. Least altered rock is composed dominantly of zeolitized shards with optics suitable for heulandite. Metasomatism converted most of this rock to microcrystalline albite and quartz. Field relationships suggest that connate waters driven from associated marine mudstones by compaction appear to be the only feasible source of soda-rich fluids.

In two andesitic lithic-crystal tuffs, partial or complete albitization of plagioclase was not accompanied by significant changes in chemical composition, nor was clinopyroxene altered. Hydrous lime-rich alteration products occur as tiny inclusions (pumpellyite?) in albite and as microcrystalline aggregates (prehnite?) forming a discontinuous network interstitial to clastic grains. The patchy pattern of alteration, even on a microscopic scale, suggests that local availability of interstitial water for reaction and catalysis controlled its progress, although the underlying impulse was doubtless metastability of calcic plagioclase.

SOLUBILITY OF ANHYDRITE IN WATER FROM 100°C. TO 275°C. AND 1 BAR TO 1000 BARS

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The solubility of anhydrite in water was determined from 100°C. to 275°C. and from 1 bar to 1000 bars with specially designed hydrothermal-solution equipment. A stainless-steel pressure vessel encloses a chemically inert variable-volume tetrafluorethane (Teflon) cell from which an internally filtered liquid sample can be withdrawn with negligible disturbance of equilibrium conditions. Experimental mixtures were stirred by action of a Teflon-coated bar magnet turned by an externally applied pulsating magnetic field. Equilibrium was attained in 48 hours or less. $CaSO_4$ percentages were determined to better than ± 1 per cent of the value reported.

Anhydrite solubility decreases with increasing temperature and increases with increasing pressure. At 100 bars and 100°C., weight per cent $CaSO_4$ is 0.085; at 100 bars and 275°C., 0.0015. At 100°C. and 1 bar, weight per cent $CaSO_4$ is 0.074; at 100°C. and 1000 bars, 0.210. Our solubilities measured at the vapor pressure of the system agree closely with data of other workers.

Geologic conclusions are: (1) anhydrite will not precipitate from initially saturated solutions migrating toward the earth's surface in fissures in rocks possessing a "normal" geothermal gradient because the increase in solubility caused by decreasing temperatures more than compensates for the decrease in solubility caused by decreasing pressure; and (2) anhydrite would precipitate from saturated solutions moving from high to low pressure at constant temperature, as would be the case in and near fissures toward which a fluid-pressure gradient exists.

USE OF THE TEMPERATURE-GRADIENT FURNACE TO DETERMINE EQUILIBRIUM SULFUR PRESSURES OF METAL SULFIDE REACTIONS

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Sulfur pressures of univariant metal sulfide-sulfur gas equilibria, of the form $MS_2 \rightleftharpoons MS + S_{(gas)}$, are of considerable interest in problems of sulfide mineral genesis. However, sulfur-pressure measurement at high temperatures is difficult because sulfur reacts with most laboratory materials. A rapid and convenient new method has been devised to measure sulfur pressures by a dew-point technique which utilizes a furnace designed to establish a zone of constant temperature at one end of the furnace and a controlled temperature gradient along the rest. Temperatures are measured by thermocouples positioned along the furnace core. Metal sulfides and sulfur gas are equilibrated at constant temperature at one end of a sealed evacuated glass tube, the other end of which is a capillary along which a falling temperature gradient has been established. Sulfur liquid condenses in the cooler portions of the capillary, creating an interface between liquid and gas where the temperature is such that liquid and gaseous sulfur can coexist at the pressure of the system. From the temperature at the interface the sulfur pressure can be evaluated from known sulfur vapor pressure data. Sulfur pressures thus determined together with sample temperatures determine points on the sulfur pressure versus temperature curve representing the univariant equilibrium. Data on systems Cu-S and Fe-S determined by this method agree well with data of previous workers. The method is of general use for studies of multi-phase equilibria which involve gases for which vapor-pressure data are known.

EVOLUTIONARY TRENDS IN CLYPEASTEROID ECHINOIDS

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The holectypoid ancestor of the clypeasteroid echinoids had no food grooves, possessed continuous interambulacra that were much wider than the ambulacra, and the periproct was marginal, distant 8 to 10 pairs of postbasicoronal plates from the peristome.

Among the clypeasteroids these characters evolved independently of one another. The earliest recorded members of the group, from the Maestrichtian of the Old World, assigned to the genera *Echinocyamus* and *Fibularia* lack food grooves, have narrow continuous interambulacra on the oral surface, and have the periproct near the peristome. Because of the position of the periproct as well as other specialized characters these Cretaceous species cannot be ancestral to most geologically younger clypeasteroids. The suborder Laganina to which these echinoids belong is in part characterized by continuous narrow interambulacra; by simple, unbranched food grooves or none; and usually by an advanced position of the periproct. The suborder Clypeasterina, with its earliest recorded members in the Eocene, is in part characterized by orally discontinuous interambulacra; simple unbranched food grooves; and a periproct near the ambitus. The suborder Scutellina, first recorded from lower Eocene, is in part characterized by periproct variable in position; interambulacra mostly continuous in early members and discontinuous later; and food grooves that tend to become complex. The suborder Rotulina is enigmatic, comparing with the scutellinids in character of the interambulacra and food grooves but more closely related to the laganinids by position of the periproct and features around the apical system.

MODAL VARIATIONS WITHIN AN OUTCROP OF THE SAGEHEN ADAMELLITE

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Stable estimates of modal parameters can be obtained only after the sampling problem has been solved. To aid in solving this problem, the source and magnitude of modal variation within an outcrop was determined for an adamellite of the Northern Inyo Range, California.

Three levels of variation within an outcrop (traverses within sections, sections within hand samples, hand samples within outcrops) were studied. This adamellite is equigranular with an average grain size of 2 mm and an I.C. number of 50. The modes were determined by micro point counting. Sixteen traverses of 100 points each were made on 4 thin sections from each of 4 hand samples.

As shown by the chi-square index of dispersion, the traverses within sections were generally not random samples of a homogeneous population. However, nonsignificant probabilities were found for the heterogeneity chi-square of the major minerals. Using the nested-samples model of the analysis of variance, no significant differences between duplicate counts of a thin section were found at the 99 per cent level. The "mafics" yielded significant differences among thin sections from the same sample. This is probably due to their arrangement in the sample. Modal quartz differs significantly among hand samples.

These variations show that, for efficient sampling, either a separate plan is required for each mineral or an adequate compromise must be determined by an initial study of each problem.

DIABASE–GRANOPHYRE RELATIONS IN THE ENDION SILL, DULUTH, MINNESOTA

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The gently dipping 1500-foot thick Endion sill intrudes Keweenawan flows at Duluth, Minnesota. From the bottom to the top of the body, there is a gradual transition from diabase (60 per cent of exposed mass) through intermediate rock (granodiorite) to granophyre (adamellite). Fractional

crystallization of basaltic magma produced a great thickness of basic and intermediate rock types which accumulated predominately in the lower portions of the sill, and probably in the end stage of an aqueous, salic, alkalic liquid. It is proposed that, owing to initial inclination of the sill, part of this salic fraction migrated up dip, accumulated and reacted with portions of the diabase and intermediate rock, and completed crystallization at the presently exposed level. Alternatively, much or all of the Endion sill granophyre may represent a separate unrelated intrusion. In either case the sill is composite. Bulk compositions of cryptoperthites indicate that both granophyre and intermediate rock crystallized at magmatic temperatures.

Compositional uniformity of the clinopyroxene and lack of iron enrichment in felsic portions of the Endion sill may be the result of accumulation of H_2O and the presumed maintenance of nearly constant partial oxygen pressure during crystallization. This mechanism would furthermore account for inferred late magmatic solid solution between alkali feldspar and $KFe^{+++}Si_3O_8$, with subsequent subsolidus exsolution of hematite.

METAMORPHISM AND GRANITIC INTRUSION IN THE GLACIER PEAK QUADRANGLE, NORTHERN CASCADE MOUNTAINS OF WASHINGTON

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A northwest-trending series of regionally metamorphosed rocks includes a lower thick unit of pelitic schists with subordinate amphibolites and granulites, and a higher unit of granitic gneisses with local intercalations of amphibolite and hornblendite. Typical migmatites locally predominate.

Original geosynclinal shales, if pure, formed mica schists commonly with kyanite or staurolite or, if impure, formed calc-mica schists or hornblende-mica schists. With increase of original impurities mica schists grade into para-amphibolites. Tuffaceous sandstone or slightly argillaceous dolomitic sandstone formed quartzitic hornblende granulite and garbenschiefer. Basic volcanic rocks became orthoamphibolites. Pure limestones and quartz sandstones were rare.

Progressive metamorphism was synkinematic, at least in early stages. Postkinematic recrystallization weakened earlier schistosity; in some isochemical rocks this produced granulites and garbenschiefer, and, where accompanied or preceded by alkali and silica introduction, weakly gneissose to directionless quartz dioritic to granodioritic rocks resulted. In general, highest grade attained was kyanite zone. Retrogression was minor and local.

Quartz dioritic and related magmatic rocks were discordantly emplaced in the vicinity of Miners Ridge. Autometamorphism resulted in crystalloblastic textures, clearly superimposed upon *earlier* typically igneous features in many rocks. Where present, epidote has formed at expense of plagioclase or hornblende.

Although megascopically similar, older metamorphic granitoid rocks are distinguished from younger igneous ones by having: (1) early crystalloblastic features, locally with superimposed general, weak cataclasis which suggests mobilization; (2) abundant idioblastic (contemporaneous) epidote; (3) gradational contacts, through wide zones of migmatites, with adjacent schists; (4) numerous inclusions (skialiths, etc.) aligned with country-rock structures.

PRECAMBRIAN CORUNDUM-BEARING ROCKS IN THE MADISON RANGE, SOUTHWESTERN MONTANA

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The corundum-bearing rocks occur with Precambrian gneiss, schist, amphibolite, quartzite, and minor iron formation and were considered igneous by Heinrich (1949; 1950) and metasedimentary by Clabaugh (1952). At three places feldspathic gneiss, composed of alkali feldspar and biotite with accessory rutile and skeletal corundum, contains up to 10 per cent large corundum crystals sur-

rounded by alkali feldspar halos. These rocks parallel the regional foliation and grade laterally into rocks composed entirely of sillimanite and muscovite. Apparently high-grade metamorphism of an aluminous sediment produced syenite gneiss; next, perhaps in this phase (Clabaugh, 1952) unoriented corundum ovoids formed by replacement of the gneiss with addition of aluminum and potassium. The final step was local development of sillimanite-muscovite rocks. Hornblendite and amphibolite occur at each of the three corundum localities. Relict pyroxene in amphibolite and other evidence suggest granulite-facies metamorphism followed by amphibolite-facies metamorphism. Reid (1957) noted similar evidence and conclusions in the Tobacco Root Mountains immediately west. The gneiss and ovoids probably formed during the granulite (?)-facies metamorphism which Reid believes was accompanied by feldspathization. Sillimanite and muscovite probably developed during the amphibolitic metamorphism, and there is some evidence of feldspathization of the amphibolites.

Zircon studies suggest a sedimentary origin, but trace-element content does not support a bauxite origin. Nearby iron formation suggests that the aluminous sediment may represent prolonged weathering and may be a significant mappable zone. In other areas corundum is associated with ultrabasic intrusive rocks, but variable composition of the hornblendite and amphibolite suggests that they are para-amphibolites.

EARLY TERTIARY FLORA FROM THE LOWER FRASER RIVER VALLEY, BRITISH COLUMBIA

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Outcroppings of continental sediments in the lower reaches of the Fraser River valley have yielded numerous fossil land plants. The sediments from which the specimens were collected have been mapped as the Burrard, Kitsilano, and Huntingdon formations. Earlier investigators considered the flora of the Burrard as Eocene, whereas some considered the Kitsilano to be Oligocene. The flora as now known contains about 60 species. Among the genera are *Macclintockia* and *Lygodium*. The flora shows remarkable uniformity and contemporaneity, and the plants suggest a Middle Eocene age for the formations. The plants indicate a warm to subtropical climate characteristic of this part of the Tertiary. Microfossil evidence based on pollen supports these opinions.

PROBLEMS IN GLACIAL CHRONOLOGY OF NORTHERN WASHINGTON

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Studies of continental glaciation in northern Washington have utilized a variety of criteria for establishing the age of various episodes. Depending on the availability of field evidence, different workers have used stratigraphy, weathering, erosion, physiographic expression, rate of talus accumulation, relationship to units in the Palouse loess, bedrock topography, and radiocarbon analysis. Weathering, topographic expression, and radiocarbon dating support correlation of the last major glacial advance as Wisconsin. However, substage correlations result in major inconsistencies:

(1) The last advance in Puget Sound has been referred to Tazewell (13,700 BP), while its apparently equally weathered and supposedly synchronous counterpart across the Cascades, the Okanogan lobe, has been designated Mankato (10,000 BP?);

(2) Restricted valley glaciers a few hundred feet thick, sharing the catchment divide in southern British Columbia of the mile-thick Okanogan lobe, have also been dated as Mankato (post 11,300 BP);

(3) The Spokane lobe has been suggested to be early or pre-Wisconsin although north of its terminus it merged with the Okanogan lobe;

(4) East of Grand Coulee the stratigraphic evidence available in Puget Sound and Cascade areas is almost lacking, and nearly every ice margin so far suggested has been disputed; little agreement exists here or in northern Idaho as to whether recognizable moraines are terminal or recessional.

Until the precise relationship of ice advances within northern Washington itself can be established,

correlation at the substage level with Midwestern chronology cannot be satisfactory. Present attempts fail because of insufficient field work, lack of stratigraphic information, and scarcity of radiocarbon dates.

FAULTING IN NORTHEASTERN SONORA, MEXICO, IN 1887

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Faulting associated with the Sonora, Mexico, earthquake of May 3, 1887, extends farther than previous mapping indicates, particularly south of the Bavispe River. This earthquake rates among the strongest experienced in the western United States.

The fault extends southerly from a few miles south of the Mexico–United States boundary for about 50 miles.

Right-lateral movement of up to 20 feet displaces andesites and leaves scarps up to 20 feet high. Near this place, a few miles north of where the fault crosses the Bavispe River, are several sharp bends, approaching right angles, with intervening, nearly straight segments several thousand feet in length. These bends have a short radius of curvature. Twenty miles to the north scarps up to 21 feet were measured.

Displacement is negligible where the fault crosses the Bavispe River, but the scarp increases to a height of many feet farther south. South of the river the recent scarp appears to follow an ancient line of faulting along the western slope of the Teras Range (Sierra de la Madera) and has been traced for 12 miles south of the Bavispe through the Cinco de Mayo mining district and beyond.

MARINE PERMIAN AT BLACK ROCK, NEVADA

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Black Rock, a prominent topographic feature of the Black Rock Desert in northwest Nevada, was first reported by John C. Fremont who, in 1844, noted the abundance of black fragments, like the cinders from a blacksmith's forge, at the base of this sharply conical hill.

The rock, generally thought to be a mass of volcanic-flow rock, received only cursory attention over the years. Recent detailed examination has shown the cone to be composed of very steeply dipping, fossiliferous, volcanic sediments and limestones. The fossiliferous beds contain well-preserved upper (?) Permian brachiopods. This is the westernmost exposure of fossiliferous Permian strata known in the State.

The Black Rock Permian consists of more than 1800 feet of volcanic sediments with variable amounts of limestone and includes a 100-foot unit of well-bedded limestone. The major portion of the sequence is 1- to 2-foot beds of andesite clasts which average about half an inch in diameter but range from a small fraction of an inch to 6 inches. The volcanic rocks consist principally of augite andesite breccia.

The volcanic sediments at Black Rock are typical of accumulations in eugeosynclines. In these belts local volcanic sources may supply volcanic detritus to adjacent areas of limestone deposition. In some fortuitous circumstances, as at Black Rock, organic remains are preserved in the more limey beds and in the dominantly volcanic detritus.

TERTIARY POLLEN FLORA FROM THE BASIN AND RANGE PROVINCE, ARIZONA

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A newly discovered microflora provides the most detailed record of Arizona Tertiary vegetation. The fossils come from tuffs near 5600 feet in the mountains 4 miles northwest of Prescott. The tuffs are tentatively referred to the Clarendonian on the basis of the regional geology and paleontology.

Most abundant are the arborescent oak, juniper, cupressus, and pine (of the pinyon type). These are the characteristic genera of brushland and woodland communities of central and southeastern Arizona today. Among nonarborescent plants, grasses, composites (including sagebrush, Ambrosieae, and others), and chenopod-amaranths are common. Except for elm, the identified genera and families (*ca.* 80 per cent of the flora) live nearby, and all are represented by pollen in recent sediments near Prescott.

The fossil flora approximates the vegetation in central and southeastern Arizona at about 4000–5500 feet (lower margin of the Upper Sonoran zone). Paleobotanical evidence thus supports the presence of late Tertiary uplands in central Arizona inferred from the regional geology. But the frequency of fossil pine pollen is low (relative to productivity of modern species) for an elevation where pine now largely dominates the vegetation of central Arizona. The inference is that the basin of deposition was lower and/or the climate drier (average annual rainfall at Prescott (5355 feet) *ca.* 18 inches) when the polliniferous sediments were deposited. The presence of *Betula*, *Alnus*, and *Ulmus* in the microflora appears to raise rather than lower the moisture requirements of the vegetation, but their scarcity suggests distant transport from more mesic uplands.

THRUST-FAULTING LIMITS IN WESTERN UTAH

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Magnitude of movement on thrust faults exposed in Basin and Range fault blocks has been difficult to estimate because extent of thrusts cannot be traced under Basin fill. Minimum displacement figures may usually be obtained by measuring the horizontal extent to which an allochthon now covers an autochthonous area, but maximum figures can seldom be determined by such direct measurement because of concealment problems. Recent mapping and stratigraphic work, however, have permitted delimitation of maximum movement on three thrust faults in Utah.

The Nebo thrust (possibly the southern continuation of the Charleston-Deer Creek thrust) has a minimum horizontal displacement of about 6 miles near Nephi, Utah. Total horizontal deformation may be twice this amount considering isoclinal folds in the allochthon. Maximum movement here may be measured by comparing the stratigraphy of the allochthon with known sections to the west in the direction from which the allochthon came. Consistent progressive facies changes in lower Paleozoic strata from the Nebo allochthon to Long Ridge and Tintic sections indicate that total displacement of the Nebo allochthon was probably no more than 12 miles.

The Pavant thrust near Kanosh, Utah, shows a minimum of 7 miles horizontal displacement, not including deformation represented by overturned folds. Maximum displacement, estimated by comparing allochthon stratigraphy with sections to the west, may be as much as 25 miles.

Horizontal deformation on the Needle thrust near Garrison, Utah, may be estimated structurally as the thrust fault passes northward into a fanfold. Shortening of 8 to 10 miles is postulated.

PRIMARY STRUCTURES IN PYROCLASTIC ROCKS OF THE OAK SPRING FORMATION (TERTIARY), NORTHEASTERN NEVADA TEST SITE, NYE COUNTY, NEVADA

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The Oak Spring formation in the Nevada Test Site consists mainly of massive to bedded pyroclastic rocks as much as 2300 feet thick deposited on an irregular surface with a local relief as great as 1500 feet.

Bedding attitudes in the basal part of the pyroclastic sequence are directly related to the irregularities of the buried surface and locally show dips as steep as 40°, although angles near 30° are more common. Units farther from the buried surface have successively lower dips because the irregularities

tend to be subdued by continued deposition, erosion, and redistribution of volcanic material. The pyroclastic units lap onto or drape over buried ridges and fill valleys forming primary anticlines and synclines.

Many other sedimentary structures including contorted strata, cross-strata, ripple marks, and erosional unconformities characterize parts of the Oak Spring formation.

In many areas tectonic tilting, folding, and normal faulting have modified the primary folds in the pyroclastic rocks. Because of the similarity of the primary folds, formed during deposition of the Oak Spring formation, to folds formed by tectonic activity, care is required to distinguish the two types.

STRUCTURAL GEOLOGY AND STRUCTURAL CONTROL OF MINERAL DEPOSITS IN AN AREA NEAR NOME, ALASKA

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Two structure systems have been delineated in the regionally metamorphosed bedrock of an area near Nome, Alaska. The older system, formed penecontemporaneously with the metamorphism, once consisted of a series of broad, open folds 10–30 miles wide and as much as 100 miles long, which extended northward across central Seward Peninsula. Later deformation gave rise to the younger system of structures, leaving only deformed relict parts of the older folds.

The younger structures reflect strong vertical movement. The principal structure is an eastward-trending uplift which formed the present Kigluaik Mountains. The north and south margins of the uplift and the mountains are marked by steeply dipping normal faults, and the center of the uplift is marked by the axis of an arch along which lie the highest points in the range.

Other structures belonging to the younger system include folds of considerable size, which formed on the crumpled limbs of the older folds, and a group of northeast-trending transcurrent faults. Gold-bearing lodes of the Nome goldfields are closely associated with both types of younger structures; the richest gold beach placers of the area were derived from a mineralized transcurrent fault which intersects the coast near Nome.

GARLOCK AND DEATH VALLEY FAULT ZONES IN THE AVAWATZ MOUNTAINS, CALIFORNIA

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The rugged Avawatz Mountains, south-southeast of Death Valley, are crescentic in plan and have a prominent front that bulges broadly northeastward. The main mass of the range is a structurally high, lenslike block composed chiefly of earlier Precambrian plutonic and metamorphic rocks. This block, 14 miles long and 1–5 miles wide, is bounded and broken by faults of large displacement. Southwest of it a slightly larger and structurally much lower block contains thick sections of layered Mesozoic and Tertiary rocks.

The east-trending Garlock fault zone and the southeast-trending Death Valley fault zone, each 1–3 miles wide, join in the northwestern part of the range, where individual breaks truncate one another in a highly complex pattern. Within the area of junction are numerous fault-bounded slices of later Precambrian, Paleozoic, Mesozoic (?), and Cenozoic rocks; these are especially common along the flanks of the range. In a broad way, each fault zone partly merges with and is partly deflected by the other. Evidence of strike-slip movement and much stronger evidence indicating vertical displacements of tens of thousands of feet are present along both fault zones.

Nearly all the faults dip steeply, and none can be interpreted as a major thrust. The plexus of breaks is resolved beyond the area of junction into two major fault zones about 4 miles apart. These

trend southeastward toward Old Dad Mountain and the Providence Mountains. Associated breaks trend south-southeastward toward the Soda Mountains, but these appear to be second-order features.

PALEOZOIC SECTION IN THE ARROW CANYON RANGE, CLARK COUNTY, NEVADA

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Ordovician through Permian rocks are approximately 10,000 feet thick. Cambrian black dolomite and fossiliferous, argillaceous limestone are unmeasured. Ordovician rocks include 2434 feet of Pogonip Group comprising seven limestone or dolomite formations, 103 feet of Eureka quartzite, and 337 to 388 feet of Ely Springs dolomite, with a fossiliferous upper member. The Silurian Laketown dolomite thins southward from 403 to 257 feet because of pre-Devonian erosion. Three new Devonian formations and the Crystal Pass limestone aggregate 1970 feet. The lowermost 320-foot, buff, cliffy dolomite formation contains *Acrospirifer kobhana* at the base and is capped by a *Stringocephalus* biostrome. Above this a 300-foot, bench-forming, buff dolomite and limestone formation is succeeded by 1070 feet of black limestone cliffs with interbedded dolomite and quartzite. The Crystal Pass limestone is 229 to 280 feet thick. The Monte Cristo limestone, 1415 to 1467 feet thick, includes all Hewett's members except the Arrowhead limestone. The 3486-foot Bird Spring formation comprises five units. The basal, 79-foot, dark-gray, medium-grained limestone unit includes a calcareous basal sandstone. *Stigmaria* sp. occurs associated with marine fossils just below the base of the prominent succeeding black shale and argillaceous limestone unit. *Rhipidomella nevadensis* occurs at the base of the succeeding cyclic limestone unit. Above this, a unit of interbedded limestone and argillaceous, cherty limestone is succeeded by a white, cliffy dolomite and limestone unit. The top of the Bird Spring formation is not exposed.

PATTERNS OF STRUCTURAL GEOLOGY IN THE NORTHERN PART OF SOUTHEASTERN ALASKA

Ernest H. Lathram

Large blocks separated by major lineaments in northern southeastern Alaska exhibit different structural patterns. In the Coast Range belt, on the mainland, closely spaced folds trend northwest, are isoclinal, and overturned to the southwest. Plutonic rocks are usually well foliated, parallel to the foliation of older rocks; migmatite is common. Major structures of the Admiralty Island block are broad northwest-trending composite folds, most overturned to the southwest but some to the northeast. Large plutons are moderately foliated, migmatite is common. In the Chilkat Range block, south of L. 59° N., closely spaced folds trend northwest, are isoclinal and overturned to the southwest in the east, tight and asymmetrical with steep southwest limbs in the west. Plutons are small, unfoliated, have sharp contacts and narrow contact metamorphic zones. From 59° N. to Takhin River folds apparently trend northeast; plutons are large and well foliated. In the northeast Chichagof block (northeast of Mud Bay–Sitkoh Bay lineament) folds are broad, symmetrical, trend west-northwest. Plutons are small; most of them are unfoliated, have sharp contacts, and show few contact metamorphic effects. In the western Chichagof belt the folding is not well known. Beds dip predominantly southwest. Plutonic rocks are commonly well foliated, parallel to foliation of older rocks; migmatite is common.

Most faults are steep. Northwest-trending faults predominate, most are right lateral or reverse, northeast side upthrown except in the west Chichagof belt. Most east-trending faults are normal, north side downthrown. Some northeast-trending faults are apparently left lateral. East-, northeast- and north-trending faults are rarely well expressed in metamorphosed areas.

PORPHYRY INTRUSIVE ROCKS OF THE MANHATTAN DISTRICT, NORTHERN FRONT RANGE, COLORADO

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A belt of intrusive rocks regarded as of probable Laramide age by Lovering and Goddard (1950) trends northeast in the Front Range west of Fort Collins, Colorado. It parallels the central Colorado intrusive belt to the south and contains granodioritic and monzonitic porphyries similar to those in the larger and better-known belt.

In the Manhattan mining district the country rocks are Precambrian quartz-biotite schist, hornblende schist, and granitic rocks. Detailed mapping shows the porphyry to be dikes, sills, and small stocks. Tabular bodies are most abundant and are from a few feet to 200 feet wide and up to 1½ miles long. Most of them are discordant to the country rock foliation but locally parallel it. The stocks are irregularly shaped and formed at the intersections of dikes. Most of the dikes follow east-west and northwest-southeast joints and shear zones that parallel major Laramide structural trends. Arcuate outcrop patterns suggestive of ring dikes result where dikes followed gently curving schist–granite contacts.

Although mineralized shear zones are common near the intrusive rocks, there is little evidence of wall-rock alteration indicative of potentially commercial deposits.

DISTRIBUTION OF THE CHEMICAL ELEMENTS IN THE SALINES OF SALINE VALLEY, INYO COUNTY, CALIFORNIA

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Saline Valley is a deep depression in the Basin and Range province containing NaCl-Na_2SO_4 deposits of Pleistocene and recent origins.

The distribution of major and minor constituents in the salts, brines, muds, ground waters, and springs of Saline Valley were investigated. Several centers of evaporation were found on the playa, and their assemblages of major and minor constituents differ.

Anomalous concentrations of Li, K, Rb, Mo, W, I^-, IO_3^-, $CO_3^=$, $SO_4^=$, and borates were found in the salines, some of which were traceable to source areas. Li, K, Rb, and to a certain extent B were found to be controlled largely by clay minerals. Li, K, Rb, and Cu are taken up by clays along the playa margin, and the alkaline earths are quantitatively precipitated as carbonates along the playa margin leaving Cl^-, $SO_4^=$, $CO_3^=$, Br^-, IO_3^- and borates to concentrate in the centers of evaporation.

Anomalous concentrations of Li, K, Rb, Mo, W, I^-, IO_3^-, $SO_4^=$, $CO_3^=$, and borates were found in the salines, some of which were traceable to source areas. Many of the trace elements in the brines were found to be related to or controlled by the ratio of alkaline earths to carbonate or bicarbonate in the incoming ground water.

O^{18}/O^{16} RATIOS AND SR AND MG CONTENTS IN RECENT AND FOSSIL ARTICULATE BRACHIOPODS AND THEIR RELATIONSHIP TO THE WATER CHEMISTRY

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For recent brachiopod shells it is shown that the Sr and Mg concentrations, like the O^{18}/O^{16} ratios, depend upon temperature and the water chemistry. In shells from waters chemically similar to the

average of the oceans, the relationship of the O^{18}/O^{16} ratios to the Sr and Mg concentrations is essentially dependent only on temperature, as the water corrections for the O^{18}/O^{16} ratios and Sr and Mg concentrations are small. Samples from hypersaline waters, enriched in O^{18}, Sr, and Mg concentrations relative to mean ocean waters, have O^{18}/O^{16} ratios which are more positive and have higher Sr and Mg concentrations than samples from the same temperatures in mean ocean waters. A sample from hyposaline water, depleted in O^{18}, Sr, and Mg concentrations relative to mean ocean water, has a more negative O^{18}/O^{16} ratio and lower Sr and Mg concentrations than samples from the same temperature in mean ocean water. Therefore the relationships of the O^{18}/O^{16} ratios to the Sr and Mg concentrations in the shells can be used to distinguish samples from waters of different water chemistry.

In several fossil brachiopods (Pliocene to Mississippian) the relationship of the Sr concentrations to the O^{18}/O^{16} ratios is similar to that of recent samples from mean ocean waters, while in two other samples (Permian) it is similar to recent shells from hypersaline waters. The relationships of the Mg concentrations to the O^{18}/O^{16} ratios in two fossils are close to recent samples from mean ocean waters; in the other fossils they are diagenetically modified.

GEOLOGY OF THE PRIEST RAPIDS AND WANAPUM DAM SITES ON THE COLUMBIA RIVER IN SOUTH-CENTRAL WASHINGTON

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The master plan for development of the Columbia River called for a 175-foot dam at Priest Rapids. Permeability of a high gravel terrace constituting the left abutment was a controlling factor in the decision to split the head between two dams, Priest Rapids, now substantially completed, and Wanapum, now being built.

Priest Rapids dam is about 8000 feet long. The spillway and powerhouse, 2000 feet long, are founded chiefly on a strong basalt flow which formed the rapids. One interflow contact accepted 30 cubic feet of grout per linear foot of curtain; except for this contact, the basalt is essentially impermeable. Low terraces of gravel on both sides of the valley are spanned by earth-embankment segments; rolled-fill cutoffs extend to rock. An upstream blanket 1000 feet long seals the face of the high terrace on the left side of the valley.

At the Wanapum site the rock surface is covered by 50–300 feet of alluvium across the entire 8000-foot width of the valley floor. The spillway and powerhouse are on a buried ridge formed by differential erosion in the axial part of a basalt anticline. Positive cutoff walls are required under the earth-embankment segments of the dam, but, because the rock surface is far below river level, placement of a conventional rolled fill, in the dry, is impracticable. Cutoff walls are being constructed by digging narrow, vertically walled trenches, kept full of bentonite slurry to prevent caving, and backfilling with well-graded sand and gravel blended with the bentonite slurry.

FOUNDATION FAILURE AT MALPASSET DAM NEAR FREJUS, FRANCE

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On December 2, 1959, a 200-foot high thin-arch dam across the Reyran River in France collapsed. The resulting flood caused damage in the millions and took 424 lives. The dam, only 5 years old, had just filled for the first time during unprecedented rains.

The structure was founded on a sheared jointed mass of mica schist, and failure occurred under the central left abutment, where intersecting joint planes roughly parallel to the arch created a V-shaped mass of crushed rock overlying a clay seam. The left side of the arch was largely founded on the crushed wedge.

Apparently, movement resulting from saturation, weakening, and movement of this wedge transferred greater thrust to other portions of the arch. This action resulted in the movement of the small, left-end thrust block, in less competent material, about 2 feet downstream and upward a similar amount. The lower right side of the arch at channel elevation moved downstream about 2 feet, crushing the foundation rock. The left three-fourths of the dam then collapsed.

GEOLOGY OF THE ESCALANTE-BOULDER AREA, SOUTH-CENTRAL UTAH

C. Carew McFall

The Escalante-Boulder area is in the Colorado Plateau province in south-central Utah; it comprises 583 square miles on the southern slopes of the 11,000-foot, lava-capped Aquarius Plateau.

Jurassic, Upper Cretaceous, and Tertiary strata totaling 12,000 feet are exposed in the area. The pre-Tertiary beds have been involved in monoclinal folding and are overlain in angular unconformity by nearly horizontal Tertiary strata A few relatively small, normal faults cut both the Tertiary and older rocks.

In the Jurassic San Rafael group, correlation is made between the Carmel formation of the San Rafael Swell region and the beds presently called Carmel formation, Entrada sandstone, and Curtis formation in the Bryce Canyon and Zion Canyon areas and also between the Entrada sandstone of the San Rafael Swell region and the Windsor formation of southwestern Utah.

The lowest Tertiary beds, which are orange pink, are evidently correlative with the Flagstaff limestone of late Paleocene and early Eocene age rather than with the Wasatch formation.

The regional orogenic history which has been worked out in central Utah by E. M. Spieker is substantiated by the sedimentary record in the Escalante-Boulder area. Some added evidence for Spieker's pre-Flagstaff movement is the 170-foot thick cobble conglomerate at the base of the orange-pink beds. This conglomerate is apparently a by-product of folding and overthrusting to the northwest which was very likely contemporaneous with the monoclinal folding of the Colorado Plateau.

UPPER CRETACEOUS FORAMINIFERA FROM VANCOUVER ISLAND, BRITISH COLUMBIA, CANADA

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Previous geological work is summarized by Usher (1951). The Cretaceous lies in two basins, the Comox basin in the north, and the Nanaimo basin in the south, separated by a pre-Cretaceous ridge.

The succession consists of alternating marine shales and nonmarine sandstones. From bottom to top, the shales of the Nanaimo basin are named the Haslam, Cedar District, and Northumberland formations. Those of the Comox basin are the Qualicum, Trent River, Lambert, and Spray formations.

The Foraminifera represent restricted and open marine biofacies; the former is not considered here. The lower parts of the Haslam, Qualicum, and Trent River formations are typified by large lagenids together with *Gaudryina* cf. *limbata* and occasional *Globigerina*. This fauna is probably Campanian in age. The Cedar District, Northumberland, Upper Trent River, and low Upper Lambert formations contain *Anomalina henbesti* and 18 other genera. This fauna is Late Campanian in age; it corresponds to faunas of Taylor and early Navarro age in California. The uppermost part of the Lambert formation contains *Bolivina incrassata*, *Bulimina* cf. *petroleana*, spinose *Globorotalites*, *Allomorphina*, and *Globigerinella*. This fauna is early Maestrichtian in age and corresponds to P. P. Goudkoff's D-1 and D-2 zones in the Navarro of California. The Spray formation is unfossiliferous. The Campanian-Maestrichtian boundary is thus placed within the Lambert formation, slightly higher than the level used by Usher.

ADVANCE OF THE MULDROW GLACIER, 1957

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The Muldrow Glacier is located on the northeast slope of Mt. McKinley in the Alaska Range, Alaska. Since earliest observations the glacier has been stagnant with a smooth surface throughout its length. The terminus has a heavy debris cover with vegetation well established.

In January 1957 it was first noticed that the glacier appeared to be changing. In July an I.G.Y. party began studying what proved to be one of the most spectacular glacial advances ever documented. Beginning sometime in the winter of 1956–1957 and until August 1957, parts of the Muldrow and its tributaries advanced as much as 4 miles. The entire glacier has undergone a complete change. Although much of the Muldrow lies athwart a fault zone no significant seismic activity was recorded. Climatic data show no evidence of increased snowfall, and no other glacier in the vicinity shows any signs of activity.

The reservoir lag theory of Tarr and Von Engeln is proposed as a partial solution to the mysterious rapid advance. The surface of the upper part of the glacier has dropped as much as 200 feet from its position in 1954. The surface of the terminal area has thickened about 200 feet. Features around the terminus suggest that similar rapid advances occur periodically.

SEISMIC ACTIVITY IN BRITISH COLUMBIA

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The list of earthquakes from the mid-1880's to 1951 was compiled from seismological catalogues and from newspaper files. From 1951 to date, a network of sensitive seismographs has located the smaller tremors in the southwestern area. Since 1957, when these seismographs were calibrated with the Willmore bridge, magnitudes have been obtained for each earthquake. Maps showing the distribution of epicenters are shown.

DIFFERENTIAL THERMAL ANALYSIS OF SHATTUCKITE

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Dark-blue radiated shattuckite from Ajo, Arizona, is used in the differential thermal analysis. The thermal curve is traced on a Leed and Northrup micromax recorder: heating rate 12°C per minute; scale factor × 20, which corresponds to 10 microvolts per division of the graph paper; particle size of sample below 100 mesh.

The thermal curve is characterized by a prominent endothermal peak and a small exothermal peak. The endothermal peak has a peak temperature of 774°C, peak height 210 microvolts, and peak range 700°C to 800°C. The cooling effect actually starts at 430°C and increases rapidly at 700°C. The exothermal peak has a peak temperature of 980°C, peak height 60 microvolts, and peak range 970°C to 990°C.

The endothermal peak indicates dehydration and decomposition of shattuckite into cryptocrystalline tenorite, some amorphous silica, and copper silicate(?), which were identified by X-ray powder diffraction method. Sample heated to 950°C contains tenorite and cryptocrystalline alpha quartz, whereas copper silicate(?) disappears. Sample heated to 1,000°C contains tenorite, cuprite, and alpha quartz. Because cuprite has greater free energy of formation than does tenorite, some tenorite in the sample is decomposed into cuprite at about 800°C. The exothermal peak indicates the crystallization of alpha quartz.

The total loss of weight of 3.87 per cent begins at 900°C. According to the total loss of weight, the formula of shattuckite should be $3CuSiO_3 \cdot H_2O$, instead of $2CuSiO_3 \cdot H_2O$. A small percentage of the loss of weight is due to the decomposition of some tenorite into cuprite.

LARGE OVERTHRUSTS IN THE NORTHWESTERN CASCADES NEAR THE 49TH PARALLEL (WHATCOM AND SKAGIT COUNTIES, WASHINGTON, AND LOWER TOMYHOI CREEK AREA, BRITISH COLUMBIA)

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Of two westward overthrusts west of the crystalline backbone of the Northern Cascades, the lower (Church Mountain thrust = I) brings Upper Paleozoic over Jurassic-Lower Cretaceous rocks, the upper (Shuksan thrust = II) low-grade Cascade metamorphic rocks of pre-Jurassic and otherwise uncertain age over the Upper Paleozoic. After latest Cretaceous-Paleocene deposition the thrusts were folded.

Thrust I forms the large Nooksack North Fork anticlinal window and re-emerges north of the border (Tomyhoi Creek), continuing across the Chilliwack.

Thrust II is preserved east and west of the window. Its steep root southward crosses the Skagit. Farther south J. A. Vance mapped the same thrust.

At thrust II and within the highest part of the underlying plate occur mylonitic slices of pre-Carboniferous and pre-Cascade-metamorphic "basement" crystalline rocks, identical with those of the klippen mapped by R. S. Yeats 50 miles south of the Skagit. Sheared ultrabasic rocks in the thrust zone suggest a root extending to great depth.

Internally, the thrust plates are complexly folded and imbricated. Subsidiary thrusts within the Upper Paleozoic plate and klippen of the basement crystalline rocks and of the overlying upper-plate metamorphic rocks are spectacularly exposed around Tomyhoi Peak. Equally spectacular are recumbent folds within the Upper Paleozoic plate north of the border and within the upper plate southwest of Glacier.

Throughout the area, major and minor folds and cleavage confirm westward movement (disregarding superposed Tertiary deformation). Yielding is southwestward on the south, westward near the border, northwestward north of it. The system here forms a westward convex arc, marking the northern termination of the much larger, eastward convex "arc of the Pacific Northwest."

WEST CORDILLERAN METAMORPHIC AND GRANITIC EVOLUTION

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The following processes are discussed in their temporal and genetic relationships: regional metamorphism of different types (such as "Dalradian type", "glaucophanic type"); dominantly synkinematic granitization (production of migmatitic gneisses); static granitization; mobilization; anatexis; igneous granitic intrusion. As an example, the case history of the Northern Cascades is outlined.

Relations between metamorphic-plutonic and structural evolution are discussed. The great length of time commonly involved, and the repetitious nature of orogenic climaxes and of periods of thermal and chemical activation are emphasized.

REGIONAL STRUCTURE OF ROCKY MOUNTAINS IN THE JASPER AREA, CANADA*

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From east to west across the Foothills, Front Ranges, and Main Ranges of the Rocky Mountains there is a progressive increase in stratigraphic level from the Tertiary and Cretaceous of the Plains to Cambrian and Proterozoic of the Main Ranges.

The Foothills embrace several folded and complexly interlocked thrust sheets of Mesozoic and Paleozoic strata, about 40 to 100 miles in length. Northwest toward the Smoky River, Front Range structures lose stratigraphic throw, and resistant Paleozoic strata disappear beneath Mesozoic strata, and thus physiographically Front Ranges merge with Foothills. The Main Ranges, bounded on the northeast by the Pyramid thrust whose length exceeds 200 miles, consist of broadly folded Cambrian and Proterozoic rocks. Two important thrusts occur in the Mount Robson district, and a culmination is present west of Jasper.

Thrust faults consistently follow particular stratigraphic zones within the Upper and Lower Cretaceous, Mississippian, Upper Devonian, and Middle Cambrian rocks of the Foothills and eastern Front Ranges, and within the Cambro-Ordovician strata of the western Front Ranges. The Pyramid thrust may follow horizons low in the Proterozoic sedimentary succession.

Toward the northeast, the gross tectonic (strain) pattern is one of increasing complexity and decreasing persistence of thrust faults across the Front Ranges into western Foothills and decreasing complexity across the eastern Foothills. From this tectonic pattern and the presence of steeply dipping, rotated thrust sheets in the Front Ranges and Foothills, it is suggested that initiation of thrusts occurred progressively from southwest to northeast.

OBSERVATIONS OF PHASE VELOCITY FOR RAYLEIGH WAVES IN THE PERIOD RANGE 100–400 SECONDS

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Phase velocity as a function of period has been determined for Rayleigh waves in the period range 100–400 seconds. The results were derived from a study of seismograms from the Southeastern Alaska earthquake of July 10, 1958, and from published data on the Assam earthquake of August 15, 1950. The method depends on measurement of the travel time of wave crests along an arc of known length with proper correction for change of period with distance. For observations of a single Rayleigh-wave train at a single pair of observing stations crest identification is uncertain and so too is the resulting phase-velocity period curve. A set of phase-velocity curves may be computed, each corresponding to a different choice of crest identification. Only one of these is consistent with the data from several earthquakes and several pairs of observing stations. In the present work, high precision in phase-velocity measurement is achieved by using the observations of the Rayleigh waves R_3 and R_8 at Pasadena of the Assam earthquake. Data from the Southeastern Alaska earthquake are used to resolve the ambiguity resulting from uncertainty in crest identification. The final phase-velocity curve is estimated to be accurate to within 1 per cent in the range of periods 100 to 400 seconds.

STRATIGRAPHIC RANGE OF *OGYGOPSIS*

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The trilobite genus *Ogygopsis* is reported in the literature as confined to beds of Middle Cambrian age. Earliest reports of the type species, *Ogygopsis klotzi*, from the Canadian Rockies suggested a re

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striction to beds high in the Middle Cambrian succession. Later work by Rasetti in the same area demonstrated a range throughout nearly all the Middle Cambrian strata. The genus and its synonym or close relative *Taxioura* have also been reported from Middle Cambrian strata in the Wasatch region of Idaho and Utah, from northeastern Washington, and from the Inyo Range, California.

Recent study of the Inyo region has demonstrated that *Ogygopsis*-bearing beds, reported by Kirk as Middle Cambrian, clearly underlie strata containing *Olenellus* and other elements of the late Early Cambrian fauna. Detailed mapping throughout the Inyo region has ruled out the possibility of overthrusting as an explanation of the seemingly anomalous occurrence.

Further confirmation of the extension of the age of *Ogygopsis* is found at Miller Mountain, Nevada. The Miller Mountain formation, reported as Lower Cambrian on the basis of olenellid materials, has yielded a variety of faunas including abundant *Ogygopsis* from its upper beds. Of special significance is the occurrence of *Olenellus* and *Ogygopsis* on the same bedding surface. Clearly the genus *Ogygopsis* has a stratigraphic range from upper Lower Cambrian through Middle Cambrian.

SOME OBSERVATIONS OF LONG-PERIOD SEISMIC WAVES

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Comparison of seismic waves recorded by similar long-period seismographs at a variety of geographical locations provides additional information on several kinds of seismic-wave propagation. The *PL* wave—*i.e.*, the long-period wave train following the initial P-wave at small to moderate epicentral distances—is widely recorded throughout the world. This wave appears to be controlled by the near-surface wave guide and is potentially of value for studies of crustal and mantle structure. The dispersive properties of most of the surface waves recorded at all stations may be explained quantitatively through the use of normal mode theory for structures approximating the continental or oceanic crust-mantle systems, or a combination of the two. Certain differences in the recorded waves do exist, however, which depend upon the path and, in some cases, apparently upon the site of the recording station.

BRANNERITE WITH GOLD FROM PLUMAS COUNTY, CALIFORNIA

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Brannerite is associated with gold at the Little Nell "mine", located at an elevation of 3300 feet in the SE ¼ sec. 35, R. 8 E., T. 23 N., Bucks Lake quadrangle, Plumas County, California, on the north slope of the canyon of the Middle Fork of the Feather River. Long ago gold was mined here and at several nearby localities. Radioactivity was detected by Mr. Perry L. Jones, one of the holders of claims in the area, in old stopes, now caved and partly reopened, on both sides of a nearly vertical 5-foot albitite dike striking N. 45° W. Brannerite was identified early in 1957 in specimens brought in by Mr. Jones, who later kindly guided the writers on visits to the locality.

The rock on both sides of the dike is a soft, lustrous, black schist, mapped by H. W. Turner (1898) as Calaveras formation. The schist is mostly fine-grained dolomite, talc, and graphite with minor chlorite and quartz and scattered specks of pyrite. The stopes are in this rock which was mined to the walls of the dike. The dike rock consists of abundant, partly sericitized, albite phenocrysts, up to .5 cm, and scarce, slightly larger, quartz phenocrysts in a sericitized groundmass with scattered minute pyrite cubes. Narrow, vuggy veins of clear albite with some isolated quartz crystals cut the dike transversely. Some veinlets of dolomite are also present. Brannerite, mostly in broken crystals, up to 1 cm long, is confined to a narrow zone along the dike wall and adjoining fractures. Some is in the albite vugs. Gold, where in contact with brannerite, coats the broken crystals and is clearly later.

The brannerite is metamict and of density *ca.* 4.9. Heated fragments yield an X-ray powder diffraction pattern identical with that of type brannerite. Much of the brannerite has a yellow alteration coating of cryptocrystalline anatase.

ENIGMATIC CRETACEOUS PELECYPOD GENUS *MEEKIA*

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The genus *Meekia* was proposed by Gabb in 1864 to include three new California Upper Cretaceous pelecypod species: *M. sella*, *M. radiata*, and *M. navis*. The genus is known only in deposits bordering the North Pacific Ocean, and by far the largest number of specimens is reported from the west coast of North America. The temporal range of the genus extends from Albian through Maestrichtian, and at least a dozen species having restricted temporal ranges can be recognized. Of Gabb's original species the stratigraphic position is known only for the type species *M. sella*; it is restricted to the Maestrichtian. *Meekia cuspidata* (Whiteaves), based on internal impressions, from Maud Island, B. C., may be of Albian age. The age of *M. radiata* is unknown; *M. navis* probably is not a *Meekia*. All other species are as yet unnamed.

The genus has been placed in the families Tancrediidae, Trigoniidae, and Verticordiidae, but belongs in none of them. The systematic position is still in doubt. Internally the shells show a much modified lucinoid dentition and an entire pallial line. Shells of Santonian and younger age gape at both ends.

All species seem to have inhabited a similar and somewhat restricted environment. *Meekia* in association with a characteristic assemblage of other genera is found commonly in coarse to medium-grained sandstone, suggesting a shallow-water habitat.

GEOLOGY OF THE FRASER VALLEY FROM HOPE TO EMORY CREEK, BRITISH COLUMBIA

Peter B. Read

The Fraser Valley from Hope to Emory Creek is underlain by mainly regionally metamorphosed Paleozoic and (?) Mesozoic sedimentary and volcanic rocks.

The Chilliwack group consists of iron- and magnesium-rich pelitic schists and minor basic schists of the staurolite-quartz subfacies and the sillimanite-almandine subfacies.

The Hozameen group, which generally consists of cherts, phyllites, and greenstones of the greenschist facies, is raised to the almandine amphibolite facies at its western boundary. The Custer granite gneiss is an ancient complex of sedimentary and volcanic rocks. During the regional metamorphism of the Custer, it formed gneisses and pegmatites, became mobile, and, limited by the structure of the surrounding rocks, moved into an area of less intense metamorphism. The movement caused a shearing of the Custer to form augen gneisses and of the adjacent rocks to form phyllonites. Later release of stresses caused closely spaced faulting of the Custer and the wall rocks. A band of sheared quartz diorite and gneiss separates the Hozameen group from the Custer. The quartz diorite intrudes both units. Unmetamorphosed conglomerates of the Jackass Mountain group unconformably overlie the Custer.

A northerly trending dip-slip fault formed above the Lower Miocene has downfaulted the rocks east of the Chilliwack group. The fault extends from Spuzzum to Chilliwack River and possibly into northern Washington. Its trace south of Hope has been partly obliterated by the intrusion of the younger Chilliwack batholith. An early period of folding (Jurassic?) is associated with the movement of the Custer, and a later period (post-Early Cretaceous) with the formation of a northerly trending anticline that occupies the center of the Fraser Valley.

TOURMALINIZED FRANCISCAN SEDIMENTS AT MT. TAMALPAIS, MARIN COUNTY, CALIFORNIA

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An interesting type of rock alteration involving boron metasomatism occurs at the East Peak of Mt. Tamalpais, where sediments of the Franciscan formation are tourmalinized. These altered rocks, which crop out in an irregularly shaped area roughly a quarter by half a mile in maximum dimension, were largely graywacke and shale, but now consist chiefly of quartz and brown tourmaline. Alteration took place principally by replacement of feldspar and matrix material by fine-grained tourmaline. The clastic quartz grains apparently were not affected, except possibly in some of the highly altered, fine-grained rocks where relict textures are not recognizable. Tourmaline commonly constitutes 25 per cent or more of the rock and in places accounts for more than 50 per cent. One specimen of tourmalinized graywacke, clearly identified by its relict textures, yielded 5.50 per cent B_2O_3. The analysis further shows the probable removal of much of the CaO, K_2O, and Na_2O in the rock. Otherwise the analysis is essentially similar to those available of Franciscan graywacke from other localities.

Tourmaline also occurs in vugs as white (rarely green) needles and stubby brown prisms. A relatively shallow origin is suggested by the abundance of these vugs in the altered rock.

EVIDENCE FOR POSSIBLE EUSTATIC FLUCTUATION IN PERMIAN SEA LEVEL

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Synchronous transgressive and regressive reef-limestone development is apparent in such widely scattered areas in West Texas and New Mexico as the Guadalupe Mountains, Chinati Mountains, and Glass Mountains. Transgressive and regressive stratigraphic relations have also been observed in marine and nonmarine units exposed in the Grand Canyon, Arizona, in eastern Nevada, in northern and central Utah, and in western Wyoming. Limited observations in Pacific Coast regions suggest similar stratigraphic conditions. Review of literature from the Pacific and Arctic coasts of North America, and of eastern and western Asia and Europe, suggest similar transgressive and regressive relations.

Major transgression took place in Leonardian time, reaching maximum extent near the end of the epoch or immediately following the end of the epoch; in Late Wordian time; and in Medial Ochoan time. Major regressions took place in Wolfcampian, Early Guadalupian, Late Guadalupian, and Late Ochoan time.

Essentially synchronous transgression and regression, in widely scattered areas of obviously different structural behavior, strongly suggest eustatic fluctuations of sea level rather than a mutual epeirogenic control.

OPTICAL AND TWIN ORIENTATION OF SPURRITE

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Contact-metamorphosed limestone on the east flank of the Tres Hermanas Mountains, Luna County, New Mexico, contains considerable amounts of anhedral, twinned spurrite crystals. Although the crystals have no planar boundaries, plane-bounded zonal growths are common. Two twin laws which produce 30-degree wedge-shaped segments have been noted. Previous descriptions of spurrite from Scawt Hill, Ireland, Velardeña, Mexico, and Crestmore, California, all refer to two twin planes at approximately 60°, but much confusion and inconsistency are apparent in these descriptions.

Suitably oriented twins of spurrite several millimeters in diameter were removed from thin sections after determining their optical orientation, and X-ray diffraction patterns of the several twin segments were obtained by the precession method. This technique permits the determination of cleavage, optical, and lattice orientation on the same sample. The diffraction patterns display pseudo-orthorhombic and pseudo-hexagonal symmetry. A prominent cleavage appears parallel to (001), and a poor one parallel to (100). The zonal-growth boundaries correspond to the planes (001), (100), (201), $(20\bar{1})$, and $(20\bar{7})$. The optical orientation is: X = b, $Z \wedge$ c = 59° to 67°. Simple and polysynthetic twinning occur with the composition planes $(20\bar{5})$ and (001), respectively. In a few instances simple twinning occurs alternately on each law, producing sixlings which appear, in thin section, as twelve 30-degree segments.

LOVE-WAVE DISPERSION IN A HETEROGENEOUS SPHERICAL EARTH

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The equation of motion for Love waves in a heterogeneous spherical earth, with suitable boundary conditions, has been solved numerically, using the modified Adams method. This method of solution of the dispersion problem is similar to that previously described by Satô for surface-wave dispersion in a heterogeneous flat earth.

The fundamental and several higher radial modes of vibration have been calculated for the Jeffreys-Bullen model and also for one proposed by Miss I. Lehmann as a result of shear body-wave studies.

PLIOCENE SILICIC IGNIMBRITES AND BASALT FLOWS IN THE BELLEVUE QUADRANGLE, IDAHO

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A three-fold rhyolitic(?) ignimbrite sequence lies unconformably on Challis volcanic rocks, on sedimentary rocks of Carboniferous age, and on rocks of the Idaho batholith along the north-central margin of the Snake River Plains. Tuff A, the lowest, consists of clinopyroxene-bearing, crystal-poor, thin flow units with black glassy bases and highly welded upper parts. The lower ignimbrites have secondary-flow lineation conforming to the underlying topography. Tuff B is largely a single(?) thick, highly welded, yet porous, crystal tuff containing about 50 per cent coarse crystals. Tuff C consists of crystal-poor, lapilli-rich, thin flow units with black glassy bases and pumiceous upper parts.

The material of tuff A is believed to represent an early phase of crystallization of a deep, hot magma; that of tuff B, a shallower, cooler magma in an advanced stage of crystallization; and that of tuff C, a relatively volatile magma.

A quartz basalt, extruded soon after tuff B, is uniformly contaminated with about 20 per cent rhyolitic material; crystals of K feldspar, plagioclase, and quartz are resorbed and altered but are otherwise identical with the phenocrysts of tuff B and may represent mixing of basaltic and rhyolitic magma. This basalt contains highly altered gneissic xenoliths which may be equivalent to the rock that was melted to form the magma represented by tuff B.

Basalt of latest Pliocene to earliest Pleistocene age, similar to the Snake River olivine basalts, shows no contamination. Tuff B, the quartz basalt, and some of the olivine basalt extruded from the same north-northwest trending structural zone. This suggests that the rhyolitic magma was solidified by the time the olivine basalt erupted.

UNDERWATER DELTA OF FRASER RIVER, BRITISH COLUMBIA

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The Fraser Delta is being built west into the Strait of Georgia near Vancouver. Rate of advance is now shown to average across a 2½-mile front surveyed in detail 28 feet per year at the 300-foot depth and 14 feet per year at the 120-foot depth. Advance at depths shoaler than 100 feet is still slower, and here the front has locally and temporarily retreated. Interception, by dredging, of bedload sand in the lower, navigable, 20 miles of the river may be responsible for the slower growth of this upper part of the delta.

The foreset slope shows underwater gullies off the present mouth and off a mouth abandoned in 1859. These gullies stop part way down the slope, and farther on there is a series of mounds suggestive of landslide hummocks. Neither bottom topography nor bottom samples suggest that turbidity currents play an important part in the evolution of this delta front.

Most core samples are unstratified for their entire length. The sediments are predominantly silt and clay on the slope north of the main river mouth, but at and south of the mouth sand constitutes about 50 per cent. Fallout of sediment from the river water which spreads out over the Strait waters, especially north of the mouth, may contribute significantly to the sediment of the slope. Sediments display consistent increase in water content (and porosity) with depth and with distance north of the river mouth.

SEISMIC-REFRACTION STUDIES AT SEA NEAR SOUTHERN AND WESTERN ALASKA

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Seismic-refraction stations were shot in deep and shallow water near the Alaska coast in 1956 and 1957.

The deep part of the Bering Sea has oceanic structure, with crustal thickness little greater than in the north Pacific. There is a large accumulation of sediment above the crust. Profiles at the foot and top of the continental slope near Unimak give crustal thicknesses intermediate between normal continental and oceanic values. The Bering shelf is composed of material with sedimentary velocities.

The Aleutian Ridge consists of material with velocities typical of volcanic islands, resting on a crust with normal oceanic velocity and depth below sea level.

A series of profiles were made up the Alaskan abyssal plain from areas with water depth of 4 km to the base of the continental slope where water depth is only 3 km. Sediment accumulations under the abyssal plain are not great, and thicken only moderately toward land. The Mohorovicic discontinuity does not change significantly in depth along this section, despite changes in water depth.

Normal oceanic crustal velocity (between 6½ and 7 km/s) was found on all these lines, as well as in shallow water through Dixon entrance and as far inland as Duke Island, near Ketchikan.

GEOLOGY OF THE BLACKHAWK LANDSLIDE, LUCERNE VALLEY, CALIFORNIA

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Blackhawk Mountain in southern California stands at the eastern end of the rugged 4000-foot escarpment that separates the San Bernardino Mountains on the south from the Mojave Desert on the north. At the base of the mountain on the broad bajada slope of southeastern Lucerne Valley is

the Blackhawk landslide, a lobe of nearly monolithologic marble breccia 30 to 100 feet thick, 2 miles wide, and nearly 5 miles long. Geological and mechanical evidence shows that the Blackhawk landslide crossed the gently inclined alluvial slope not as a debris flow, but as a nearly nondeforming sheet of breccia moving more than 50 miles per hour.

This breccia is the youngest in a series of late Tertiary and Quaternary nonmarine sandstone, fanglomerates, and landslide breccias derived mainly from the gneiss, quartzite, Carboniferous marble, and Cretaceous quartz monzonite of the San Bernardino Mountains. All these rocks except quartzite are exposed on Blackhawk Mountain.

After deposition of the older sandstone, fanglomerates, and landslide breccias, weathered gneiss and resistant marble were successively thrust northward and upward over the uncemented sandstone. Then these rocks were deformed and further uplifted to their present positions by monoclinal folding along a northwest-trending line at the foot of the present mountain front. Finally, erosion of the gneiss and sandstone undermined the marble at the summit of Blackhawk Mountain and brought about the intermittent landsliding that culminated in the Blackhawk landslide.

GEOLOGY OF THE TEXADA IRON MINES, TEXADA ISLAND, BRITISH COLUMBIA

A. C. Skerl

This account describes the results of the geological mapping of the various pits as they have been extended and deepened during the past 4 years and of the underground exploration during the past year.

In the mine area up to 1000 feet of limestone rests on an older volcanic series, both of Late Triassic age. They were folded and then intruded by a quartz diorite stock and related dikes accompanied by the formation of skarn (mainly garnet-epidote) and magnetite with minor pyrite, chalcopyrite, and pyrrhotite.

The quartz diorite broke through the volcanic rocks and then "mushroomed" in the limestone to form overhanging structural traps that seem to have been so important in localizing the ore bodies.

The deposits of economic importance have replaced limestone or previously formed skarn.

Many of the numerous faults appear to have been active before, during, and after mineralization.

The following factors influenced the location of the ore and have proved to be valuable guides for exploration: (1) limestone with an overhanging contact of diorite, (2) proximity of the volcanic basement, (3) numerous faults with easterly strikes and various southerly dips, and (4) north-striking fold axes.

RELATIVE SPEED AND ACCURACY OF SOME METHODS OF MEASURING THE POSITION OF OPTICAL DIRECTIONS BY UNIVERSAL STAGE

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Nearly all universal-stage work, whether in petrofabric studies or in descriptive mineralogy, depends on locating such optical directions as E and O, or X, Y, and Z. These optical directions are found by manipulating the axes of rotation of the universal stage so that each optical direction is aligned to the east-west axis of the universal stage; with crossed nicols the crystal will then remain dark for all tilts on the east-west axis.

Both reconnaissance and precise methods of finding optical directions can be used. Reconnaissance methods, often used in routine identification of plagioclase composition and twin laws, and in petrofabric work, must be rapid and accurate to about ± 1–$2°$. Precise work, mainly used in careful mineralogical studies, demands accuracy to a fraction of a degree with speed of measurement a minor

consideration. A statistical study of the following methods, some of them new to universal-stage work, was undertaken to see if any method combined speed and accuracy: (1) use of interference figures, (2) directly rotating to the position of maximum extinction, (3) finding the midpoint between the two positions on either side of the position of maximum extinction where the first perceptible illumination occurs, (4) Wright's method of rotating the upper nicol slightly from the true crossed position in order to test the maximum extinction position, and (5) the slotted ocular, cap analyzer, and special accessories.

FOCAL MECHANISM OF THREE KAMCHATKA EARTHQUAKES

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Three Kamchatka earthquakes are selected in order to study the relation between *S* waves and the source mechanism. The methods of *S*-wave analysis which are applied are based on the theory of point sources and make use of the polarization of *S* observed at many stations. For a single dipole with moment source, in a central projection of the focal sphere onto a plane tangent to the sphere at the bottom, the projection of the directions of polarization of *S* determine a family of straight lines which converge to the pole of motion—that is, to the pole of the "auxiliary plane." Alternately, if the poles of the planes of polarization of *S* are plotted on a Wulff net, the locus of the poles determines the trace of the auxiliary plane on the net. Other point sources are also considered.

For two of the earthquakes selected for study the fault-plane solutions had previously been determined from the data of *P* waves. For these two cases no correspondence is found between the observed *S*-wave data and the character of the *S* motion expected on the basis of the given nodal planes of *P*, whether the source be considered as a single dipole with moment or as two superposed dipoles of opposite moments.

For the third earthquake the *S* waves are strongly *SV* polarized. Investigation of the direction of first motion of *P* for this earthquake shows that the *P* motion is compressional along all rays leaving the focus downward. No faulting mechanism can explain this combination of the direction of first motion of *P* and the polarization of *S*. The source mechanism is interpreted as corresponding to a simple force acting almost vertically downward at the source. A reconsideration of the other two shocks shows that these, too, are better explained by a simple force than by a faulting mechanism.

The earthquakes studied all occurred at a focal depth of 40–60 km. The conclusions indicate that in some earthquakes a mechanism not previously detected may operate at these depths.

S WAVES: ALASKA AND OTHER EARTHQUAKES

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The techniques of *S*-wave analysis previously discussed are here used to investigate the focal mechanism of four earthquakes. In all cases the results of the *S*-wave analysis agree with published *P*-wave solutions and conform to a dipole with moment or single couple as the point model of the focus. Further, the data from *S* waves select one of the two nodal planes of *P* as the fault plane. Small errors in the determination of the angle of polarization of *S* are shown to result in a scatter in the data of a peculiar character which might lead to misinterpretation. The methods of *S*-wave analysis which in the present instances show excellent agreement with a dipole with moment source are the same methods which in the previous paper and for a different group of earthquakes required a single-force type mechanism.

ENGINEERING NOTES ON THE HEBGEN LAKE, MONTANA, EARTHQUAKE OF AUGUST 17, 1959

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The Hebgen Lake, Montana, earthquake of August 17, 1959, resulted in spectacular surface faulting and a very large landslide among other major surface effects. While geologic and seismographic evidences of a large shock were apparent, the damage to man-made structures was remarkably small.

Hebgen Dam, about 5 miles upstream from the major landslide which dammed the Madison River, is composed of an earth and rock fill, except that it has a full-height concrete-core wall along most of its main axis. The concrete-core wall settled very little, but the earth and rock around it settled up to 6 feet and contained fissures.

Building damage was unusually slight. A number of log cabins as well as hollow-unit masonry structures were within yards of the fault scarps, and these buildings in general were not severely damaged when not directly astride the scarp. Buildings across the fault were, of course, ruined. Masonry chimneys were generally, but not universally, damaged or destroyed. Some of the log cabins shifted on their foundations, but rarely did they go off their foundations. Masonry veneer fell from some buildings. As has been noted in epicentral regions of other shocks, good construction is more important than distance from a fault.

Bridges located in poor ground areas swung back and forth. In one case the bridge swung at least 15 inches, and this violent motion damaged the reinforced-concrete supporting beams.

DIABASIC AND GABBROIC ROCKS IN THE SOUTH-CENTRAL CASCADE MOUNTAINS OF WASHINGTON

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Diabasic and gabbroic intrusive rocks in a 300-square-mile area of the south-central Cascade Mountains of Washington, 25–40 miles northeast of Mt. Rainier, represent at least two periods of intrusion. The intrusive bodies range from small, tabular dikes less than 1 foot thick to large bodies covering more than a square mile.

The older diabasic and gabbroic intrusions are early Tertiary in age and are at least in part feeders for some of the basalt flows in the Eocene (?) Naches formation. In one place, an intrusive diabase body can be traced almost continuously into a basalt flow of the Naches formation. The intrusive bodies appear to be related in time to similar rocks in the Teanaway dike swarm, approximately 20 miles to the north.

Younger diabasic and gabbroic intrusions, commonly intruding volcanic rocks of Oligocene (?) age, have been traced into some flows of the widespread Columbia River basalt (Yakima basalt) on the eastern and southern margins of the area. It is not known how much of the Yakima basalt had a local source in this area. Many of the younger intrusive bodies have a pronounced northwesterly trend, probably reflecting control by basement structures.

Petrographically, the younger rocks can generally be recognized by relatively fresh pyroxene associated with fresh or altered plagioclase. In the older basic intrusions, the pyroxene is commonly altered, and, in general, kaolinization, saussuritization, and calcification of the plagioclase are more pronounced.

EARTH-STRAIN METER INSTALLATION AT OGDENSBERG, NEW JERSEY

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A horizontal-component strain meter has been installed 1850 feet below surface in the New Jersey Zinc Company mine at Ogdensberg, New Jersey. A 200-foot fused-quartz sensing tube is located in

an exploration drift through Precambrian limestone at some distance from active mining operations. A recording room adjacent to the tube room and sufficiently large for a substantial recording installation was constructed in the same drift.

A variable-capacitance displacement transducer is being used as the detecting element. Records obtained to date show tidal strains, several well-recorded distant earthquakes, storm microseisms, and slowly varying (of the order of several days peak to trough) signals which correlate with meteorological variations.

Background noise level for periods less than those of the tidal strains is sufficiently low to permit relatively high-sensitivity recording of long-period earthquake phases. Occasional small impulsive signals are observed. These have not been definitely identified but are possibly the result of noise generated in the transducer and/or recorder circuits. Several frequency bands can be observed from the same sensing tube.

A long-period vertical seismograph is also operating in the mine. Installation of instruments to measure other components of strain and complementary parameters is planned.

DIAPHTHORITIC GNEISS IN THE NORTHERN CASCADES, WASHINGTON, AND ITS STRUCTURAL SIGNIFICANCE

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South of Cascade Pass is an interlayered unit of epidote-bearing quartz-albite gneiss and epidote-chlorite-albite schists, all of the low-grade zone. This unit overlies a heterogeneous sequence consisting mainly of biotite schists and hornblende-biotite schists with a few intercalations of marble and metaconglomerate. The diaphthoritic nature of the banded gneiss is demonstrated by medium-grade relict minerals, such as biotite, garnet, and intermediate plagioclase, in all stages of mechanical breakdown and recrystallization to the present low-grade assemblage. The original gneissose structure and layering is well preserved. Zoned epidote gives a possible record of the breakdown of mafic minerals during diaphthoresis. The underlying metasedimentary rocks are of medium grade and show little retrogression except near the contact.

The contact of the diaphthorite and the underlying metasedimentary rocks has been obscured by metamorphic convergence and has been later folded. At one locality, mapped by Misch, retrogression can be proved in the underlying schists where garnet-biotite schist is retrogressively altered to mylonitic mica schists containing chloritoid.

Structural discordance between these two units is demonstrated by the southwest-northeast trending contact of the gneiss across consistent northwest–southeast trending schistosity and compositional layering in the underlying metasedimentary rocks. Thrusting is postulated to explain the structural discordance and the proximity of rocks of differing metamorphic facies and histories.

ALKALI METASOMATISM, HUMBOLDT RANGE, NEVADA

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The Koipato group of Permian and Triassic age consists of about 4000 feet of andesitic rocks overlain by 8000 feet of rhyolitic flow, pyroclastic rocks, and detrital rocks which are pervasively silicified, albitized, and potassium metasomatized. These rocks are exposed over nearly half the 240-square-mile area of the Humboldt Range.

The andesitic rocks were evidently albitized at the time of submarine emplacement, but sodium metasomatism continued, at least locally, well into the rhyolitic stage of volcanism as evidenced by quartz-albite spherulites and veins and intensely albitized rhyolitic tuff beds high in the Koipato section. Na_2O:K_2O ratios as high as 8.0:0.2 are common.

The uppermost Koipato rocks are quartz- and K-feldspar-rich breccias, tuffs, and flows genetically

related to numerous small rhyolite porphyry intrusive bodies. These intrusive rocks cut, but are essentially contemporaneous with, leucogranite intrusive bodies. Possibly they originated from a potassium-rich residual magma of the leucogranite. Albitized rhyolites and andesites near the rhyolite porphyry intrusive bodies are enriched in potassium (and commonly alumina). Albite is generally replaced by K feldspar in the rhyolitic rocks, but locally the intense effects of both albitization and later potassium metasomatism are seen in a single outcrop.

Residual fluids of the rhyolite porphyry intrusive rocks ($K_2O:Na_2O - 7:<1$) increased the K_2O content of some of the rhyolitic extrusive rocks to as much as 12 per cent and increased that of some previously albitized andesitic rocks so that the $K_2O:Na_2O$ ratio is 3.0:1.0.

TWO HOLLISTER, CALIFORNIA, EARTHQUAKES

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Two sharp local earthquakes occurred near Hollister, California, in less than a month: (1) 0232 GCT, December 29, 1959, Richter magnitude 4.7, epicenter just north of Hollister, and (2) 0325 GCT, January 20, 1960, Richter magnitude 5.0, epicenter close to the Vineyard fault-creep station 6 miles south of Hollister. Although both shocks were felt strongly in Hollister, the patterns of intensities differed noticeably in accord with the different epicenters.

The January 20, 1960, earthquake was accompanied by nonelastic surface ground movement in the San Andreas fault zone, as shown by a University of California creep recorder installed to measure movement of one concrete floor slab of a large warehouse relative to an adjacent floor slab. Three millimeters of right-lateral movement took place during the earthquake; the time required for the offset was short, but not measurable because of the slow drum rate of the creep recorder.

Directions of first *P* motion at nearby stations on December 29, 1959, were consistent with right-lateral movement on the Hayward fault, and on January 20, 1960, they were consistent with right-lateral movement on the San Andreas fault.

The earthquake of January 20, 1960, was the sixth earthquake with Richter magnitude 5 or over to occur in the central coast region of California in the past 6 years. In contrast, only two shocks of comparable magnitude occurred in the same area in the preceding 11 years.

GEOLOGIC MAP OF LINCOLN COUNTY, NEVADA

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Since 1956, the U. S. Geological Survey, in co-operation with the Nevada Bureau of Mines, has studied the geology and mineral resources in Lincoln County, Nevada, an area of 10,600 square miles. Mineral production in the county has been approximately $189,000,000. A preliminary geologic map will be useful in evaluating the mineral potential and in guiding exploration activities. Approximately 7 per cent of the map was compiled from published maps; the rest we mapped.

The exposed rocks have been subdivided into 45 map units, which include 1 Precambrian, 7 Cambrian, 3 Ordovician, 1 Silurian, 4 Devonian, 3 Mississippian, 1 Pennsylvanian, 3 Permian, 3 Triassic, 2 Cretaceous or Eocene, and 17 Cenozoic units.

Pre-Jurassic sedimentary, Tertiary volcanic, and Cenozoic unconsolidated rocks each occupy one-third of the county. Paleozoic rocks are widely distributed, but Precambrian and Triassic rocks are confined to the southeast corner.

A Paleozoic miogeosyncline occupied most of the county. Within it as much as 42,000 feet of sedimentary rocks was deposited. These rocks thin to 9000 feet in the southeast corner by onlap of Devonian rocks onto successively older formations on a stable platform area.

Many pre-Miocene (Laramide?) thrust-plate remnants, as much as 16,000 feet thick, characteristically bring older rocks as much as 16 miles eastward over younger rocks that are generally folded into overturned synclines beneath the thrust. The basins and ranges were blocked out by normal faulting, generally in Miocene and Pliocene time, before the deposition of middle Pliocene lake beds.

ORIGIN OF ZONING IN SOME IGNEOUS PLAGIOCLASES

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A zonal sequence of oscillatory cores and thin, normally zoned, more sodic rims characterizes plagioclase in many plutonic igneous rocks, especially quartz diorites and granodiorites. The core–rim boundary is usually irregular and embayed, while the corroded core often shows a patchy zoning formed by irregular inclusions of the rim plagioclase.

The oscillatory cores are interpreted in terms of differing rates of diffusion and crystallization leading to recurrent supersaturation of the melt in anorthite adjacent to the individual crystals (Hills, 1936). The abrupt change to normally zoned rims in the zoning sequence reflects saturation of the melt in volatile materials. After saturation, agitation by the escaping volatiles promotes diffusion within the melt, equalizing the rates of diffusion and crystallization. This prevents further supersaturation, permitting uninterrupted crystallization of the rims. When a magma attains saturation during its ascent, continuous crystallization after saturation is further necessitated by diminishing solubility of volatiles in the melt with declining pressure.

The resorbed oscillatory cores support the interpretation that saturation occurred largely in response to falling pressure accompanying rise of magma. The envisioned sequence of development is: (1) deep-seated crystallization of oscillatory plagioclase *in situ* by the diffusion-supersaturation mechanism; (2) rise of the magma which with falling pressure terminates crystallization and initiates resorption; (3) continued rise which leads to saturation and separation of the volatile phase halting resorption and causing crystallization of the normally zoned rims.

Formation of the oscillatory zoning through pressure changes caused by recurrent release of volatiles explains neither the resorption, the change in zoning, nor its timing.

STROMATOPOROIDS OF THE KENNETT LIMESTONE, SHASTA COUNTY, CALIFORNIA

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A stromatoporoid fauna is present in the Kennett limestone in the SE¼ NE¼ Sec. 22, T. 34 N., R. 5 W., Mount Diablo Base and Meridian, Shasta County, California. Detailed collecting shows that Coenostea occur in varying degrees of abundance and in diverse attitudes in the upper 150 feet of a section of biofragmental limestone approximately 215 feet thick. Examination of thin sections from more than 70 specimens demonstrates the presence of at least eight species. The genus *Anostylostroma* is represented by four species, *Amphipora* by one species, *Parallelopora* by two species, and *Stromatopora* (?) by one species. Most of the species seemingly have not been described. Although none of the genera is limited to the Devonian, the acme of *Anostylostroma* and *Amphipora*, as known, is Middle Devonian. The stromatoporoids, therefore, indirectly support previous suggestions of a Middle Devonian age for the Kennett limestone at its type locality.

STRUCTURAL FEATURES OF THE HUMBOLDT RANGE, NEVADA

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The structure of the Humboldt Range in northwestern Nevada is an elongate anticlinorium of Permian and Triassic rocks that is overridden by thrust plates and nappes made up of rocks of Triassic and Jurassic age; these are cut by a system of normal faults, some of which form range boundaries.

The anticlinorium, composed of a set of canoe-shaped anticlines, trends slightly east of north across the more northerly trend of the range itself. Segments of the normal faults bounding the range diverge widely from the northerly trend, and at least one segment cuts diagonally across the range. Pliocene and Pleistocene fanglomerates derived from an ancestral Humboldt Range have been broken by normal faults and progressively tilted. Block faulting has continued into the Recent.

A synclinelike structure in the southern part of the range is interpreted as a segment of a large recumbent anticline overturned from southwest to northeast. The overturned block is further cut by a net of closely spaced normal faults. In the northern part of the range there are blocks that override from northwest to southeast and others that override from east to west. Both the north-trending folds in the main part of the range and the thrusts and nappes were developed after Early Jurassic time and probably before early Tertiary time.

TWOFOLD DIVISION OF THE COLUMBIA RIVER BASALT

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The Columbia River basalt has been sampled by 28 stratigraphic sections.

Petrographically, and also stratigraphically, the rocks assigned to this formation by Merriam, Lindgren, and Smith are divisible into two distinct varieties. The older, widespread in the Imnaha and John Day regions, is characterized by about 5 per cent olivine, a silica content of 47 to 50 per cent, and by notably higher Al_2O_3, MgO, and CaO than the younger. Many outcrops have a characteristic "greasy" appearance because of the presence of saponite after olivine and of nontronite and other clay minerals after chlorophaeite. The basalts at Picture Gorge and Turtle Cove, described by Merriam in 1901, are typical.

The younger basalts are characterized by more than 20 per cent of tachylyte, little or no olivine, a silica content of 53–54 per cent, and by notably greater amounts of K_2O and TiO_2. The Yakima basalt, defined by Smith in 1901, is mostly of this kind, and so are nearly all the basalts north of the John Day and Imnaha areas. A few late Yakima flows are more olivinic. In the lower part of the Imnaha canyon the Yakima basalt rests with distinct unconformity on flows of the older Picture Gorge type.

Because of their separation in time, differences in chemical composition, and particularly because of the absence of transitional varieties between them, these two divisions of the Columbia River basalt are considered to be products from separate magmatic hearths, and not differentiates of a hypothetical uniform magma.

ECLOGITE INCLUSIONS IN SERPENTINE PIPES AT GARNET RIDGE, NORTHEASTERN ARIZONA

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Garnet Ridge, on the Colorado Plateau approximately 35 miles northeast of Kayenta, Arizona, is a low ridge of Jurassic sedimentary rocks perforated by four serpentine pipes. The pipes contain abundant xenoliths, including many derived from the Paleozoic sedimentary rocks and the igneous

and metamorphic basement below. Malde (1954) determined that the fine matrix containing the xenoliths consists mainly of serpentine, less abundant calcite and chlorite, and minor amounts of olivine, chromian diopside, biotite, pyrope, and montmorillonite.

Eclogite inclusions are sparse among the xenoliths. The eclogites are medium-grained rocks in which bright-green pyroxene and pink to red garnet are visible megascopically. The eclogites range in density from 3.3 to 3.6. Commonly they consist of about two-thirds pyroxene and one-third garnet. Most eclogite inclusions are essentially massive, but some show a distinct alignment of the pyroxene prisms.

The pyroxene has been identified as omphacite. Rutile is a minor accessory in all eclogites examined; apatite and white mica occur in a few. Lawsonite was identified in some eclogite inclusions, and in a few it ranks as a major constituent.

PALEOZOIC-MESOZOIC FRAMEWORK OF THE CORDILLERAN GEOSYNCLINE

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The western Cordilleran Paleozoic–Mesozoic stratigraphic record appears to comprise 10 regional unconformity-bounded sequences, two of which are believed to correspond in framework content to the craton-centered sequences of Sloss *et al.* (1949) and Sloss (1959). These sequences may be roughly designated as: (1) uppermost Precambrian to lower Ordovician (= Sauk); (2) mid-Ordovician to lower Devonian (= Tippecanoe); (3) mid-Devonian to lowermost Mississippian; (4) upper Mississippian to lowermost Pennsylvanian; (5) lower Permian; (6) upper Permian; (7) upper Triassic to lowermost Jurassic; (8) mid-Jurassic to lowermost Cretaceous; (9) mid-Cretaceous; and (10) upper Cretaceous to Paleocene.

"Cascadia," as an exclusively western positive, apparently did not exist prior to Mississippian time but was present intermittently from then until late Triassic.

The so-called "Manhattan geanticline" as a "late Paleozoic positive" is believed to have been merely the easterly margin of the intermittent "Cascadia." Such an intrageosynclinal positive is interpreted, however, for the interval from mid-Jurassic to early Tertiary.

The regional depositional episodes manifested by the sequences were characterized by much greater environmental uniformity and lateral extent than previously interpreted. Most of the innumerable stratigraphic discontinuities in the present record are the consequence of the differential effects of the dozen or more, Phanerozoic, post–depositional, tectonic (deformation–metamorphism–nondeposition-erosion) episodes up to and including the presently continuing Cascadian orogeny.

MAXIMUM VERTICAL GROUND DISPLACEMENT OF SEISMIC WAVES GENERATED BY EXPLOSIVE BLASTS*

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An approximate first-power relationship was found between the maximum vertical component of ground displacement and the charge size from a number of quarry shots. The maximum vertical ground displacement, normalized to the Rainier (1.7 kt) underground nuclear shot, is presented for a

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series of explosive shots ranging from 1 ton to 19 kilotons and at distances of 1 to nearly 1000 km. The following empirical equations were found to fit the observed data:

$$A = \frac{0.65 \pm 0.15}{R^{3/2}} \text{ from 1 to 100 km,}$$

$$A = \frac{(0.013 \pm 0.003)e^{-(0.0072 \pm .0003)R}}{R^{1/2}} \text{ from 100 to 1000 km,}$$

where A is the maximum vertical component of ground displacement in centimeters and R is the distance in kilometers.

STRATIGRAPHY AND PALEOBOTANY OF THE WESTERN CASCADES OF OREGON

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The two major groups of volcanic rocks in the western Cascades of Oregon—the Little Butte [Mehama] volcanic rocks, and the Sardine [Rhododendron] volcanic rocks—contain abundant plants. In the Little Butte, five floral zones can be recognized, ranging in age from middle Oligocene (Lincoln "stage") through early Miocene (Temblor "stage", in part). In southern Oregon, all the floras indicate an Oligocene age. To the north, the Little Butte appears to be progressively younger, since in the Clackamas and Columbia Gorge areas only floras of early Miocene age are known.

The Sardine volcanic rocks appear to be of middle to late Miocene age; three floral zones are represented. The relationship of these zones to marine strata is unknown. In terms of mammalian biostratigraphy, the Sardine is Hemingfordian and Barstovian in age. No floras younger than Barstovian are known in the western Cascades proper.

All Little Butte floras, except the early Miocene Collawash, indicate a subtropical climate. The Collawash, which lived on a volcanic upland, contains many species closely related to middle Oligocene forms of Montana and Wyoming. There is considerable evidence that the warm-temperate Miocene vegetation of Oregon was derived not from the north but by extensive migrations from the Cordilleran region. The Sardine floras are composed of species either conspecific with, or derived from, Collawash species. Cooling climate during the Miocene was evidently a factor, along with the rising western Cascades, in allowing the development of an extensive coniferous forest in the highlands.

EOCENE SPECIES OF THE GENUS *BALANUS* (CIRRIPEDIA)

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The Eocene has long been recognized as the time of the first occurrence of the genus *Balanus*. Several species have been described from the Eocene of Europe and the eastern United States, but *Balanus unguiformis* Sowerby from the Auversian and Bartonian of England has long been the only Eocene species based upon opercular plates. The opercular plates are necessary for specific determination, and species described solely from the outer shell are unrecognizable at present.

A new species of *Balanus* from the type section of the Cowlitz formation in southern Washington is represented by both opercular plates and shells. This is the second record of Eocene barnacles on the Pacific Coast and the first time the opercular plates have been found. This species is interpreted as being morphologically more primitive than the English *B. unguiformis*. Both species may be assigned to the subgenus *Hesperibalanus*, although *B. unguiformis* has previously been referred to *Balanus s.s.* *Hesperibalanus*, characterized by solid parieties, appears to be the ancestral group from which the later members of the genus *Balanus* with tubes in the parieties were derived.

The pre-Eocene history and derivation of the genus *Balanus* are unknown, although possible ancestors have been found in Cretaceous deposits. However, additional collections, with emphasis on opercular plates, are needed before the ancestry of *Balanus* can be adequately determined.

ABSTRACTS OF PAPERS SUBMITTED FOR THE MEETING IN ANCHORAGE, ALASKA, AUGUST 29—SEPTEMBER 2, 1960 (ELEVENTH ALASKAN SCIENCE CONFERENCE OF AAAS)

GRAVITY SURVEYS IN INTERIOR ALASKA

David F. Barnes, Rex V. Allen, and Hugh F. Bennett

U. S. Geological Survey, Menlo Park, Calif.

In 1958 the U. S. Geological Survey began a program of regional gravity surveys in Interior Alaska. A survey of the Copper River basin was followed by three profiles across the Alaska Range and by measurements in the Tanana Valley. Reconnaissance measurements in northern Alaska will begin in the summer of 1960.

The Bouguer contour map of the Copper River basin shows two distinct gravity lows. The eastern feature has two branches which extend outward from a large low associated with the Wrangell Mountains. The second feature is a broad low occupying the western portion of the basin and centered southwest of Lake Louise. These lows are partly caused by a density contrast between sedimentary and basement rocks and probably indicate the areas of thickest sedimentary rocks.

The survey in the Tanana Valley shows a sharp decrease in Bouguer gravity west of Nenana. This gradient is believed to indicate a fault along one side of a thick accumulation of sediments beneath the Minto Flats.

PRELIMINARY INVESTIGATIONS OF THE PETROLOGY AND STRUCTURE OF THE BIRCH CREEK SCHIST IN THE FAIRBANKS AND CIRCLE DISTRICTS, ALASKA

Robert B. Forbes

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The Birch Creek schist is a heterogenous basement complex which underlies the Yukon-Tanana region. The complex includes concordant and discordant granitic masses in addition to a wide range of crystalline schists.

In accordance with the views of Cairns, Prindle, Mertie, and others, the writer has assigned the Birch Creek crystalline schists an early Precambrian age. The structural and lithologic relationships between the Birch Creek schist and adjacent Lower Paleozoic rocks have remained obscure, however, and to date no localities are known where confirmed Lower Paleozoic sediments unconformably overlie Birch Creek schist.

Recent studies of these relationships northwest of Fairbanks, where a sequence of pre-middle Ordovician sediments was believed to be in unconformable contact with Birch Creek schist, show that the pre-middle Ordovician rocks which crop out on the southeast margin of the Livengood trough are phyllitic schists similar in metamorphic grade and lithology to the Birch Creek units immediately adjacent. Crystalline schists examined along a northwest traverse from Fairbanks to the margin of the trough display a systematic decrease from medium to low metamorphic grade to the northwest. The transitional decrease in metamorphic grade continues across the disputed contact(?) zone and can be traced across the strike for several miles into the pre-middle Ordovician rocks, where phyllites eventually grade into slates.

Near Fairbanks, the foliation and minor fold axes in the Birch Creek schist generally strike northwest. Toward the margin of the trough, however, the strike of the foliation gradually shifts to the northeast, paralleling the tectonic trend of the folded Paleozoic sediments of the Livengood trough. The northeast-trending folds have been superimposed on the earlier trends in the Birch Creek schist, suggesting that the less competent low-grade rocks of the basement were again folded during the orogenic disturbance responsible for the deformation of the Paleozoic sediments of the Livengood trough.

GEOLOGY OF THE RED DEVIL QUICKSILVER MINE, ALASKA

Gordon Herreid
Red Devil Mine, Red Devil, Alaska

Since its discovery in 1933, the Red Devil quicksilver mine has produced more than 20,000 flasks of mercury. The deposit occurs in folded Upper Cretaceous Flysch sediments (graded graywacke with conspicuous sole marks), and it appears to be a late event in widespread Tertiary volcanic activity. Deposits in the Sleetmute quicksilver district contain cinnabar, stibnite, and sporadic orpiment and realgar and are characteristically associated with altered dikes and sills composed mainly of carbonate and silica. The Red Devil deposit is located at the intersections of three such altered dikes with a wrench fault zone more than 300 feet wide. This fault is probably of regional extent.

The Barometer Mountain granitic porphyry stock lies 2.2 miles south of the deposit. This body is 2 by 3½ miles in diameter and rises 2800 feet above the deepest ore mined. This great difference in elevation indicates that the stock must predate the ore.

In the mine workings the sequence of events has been: (1) folding; (2) faulting, probably with strike-slip movement; (3) dike intrusion; (4) wrench faulting and deposition of cinnabar-stibnite ore in plunging shoots along the faults at their intersections with the dikes; (5) post-ore cross faulting. The pre-dike faults appear to be identical to the post-dike wrench faults and are assumed to be an early part of the same movement. On this basis the dikes are probably not far removed in time from the period of ore deposition. This, plus the regional association of altered dikes with cinnabar-stibnite ore, makes a genetic altered dike–ore association seem likely. The deposit was localized by the favorable structural environment provided by the wrench fault.

GEOLOGY AND OIL OCCURRENCE IN THE COOK INLET BASIN, ALASKA

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The Cook Inlet basin is an intermontane, structural basin approximately 14,000 square miles in area located north of Lat. 59° N. in south-central Alaska. The known sedimentary section includes rocks ranging in age from late Triassic to Recent. Tertiary nonmarine sands, shales, and coals constitute more than half the total volume of sediments in the basin.

The structural basin was formed in early middle Jurassic time and has experienced strong peripherial uplift and erosion throughout its history. Intense folding and faulting are exhibited on the north, east, and west flanks of the basin. Several major buried anticlinal trends extend northeast–southwest through the basin interior.

Mesozoic hydrocarbon accumulations associated with anticlinal traps are found on the western side of the basin. Minor quantities of oil, gas, and distillate have been produced from sandstones of the middle Jurassic Tuxedni formation. Low permeabilities within the reservoir rocks have prevented commercial production. The oil is believed to be indigenous to Jurassic beds, the exact age and position of which are questionable on the basis of present-day stratigraphic relations.

Tertiary accumulations will determine the significance of the Cook Inlet basin as an oil province. Present oil production comes from the Hemlock zone, a distinct sandstone and conglomerate unit near the base of the Tertiary Kenai formation. Entrapment has been influenced by folding and faulting along trend of an interior basin high which lies adjacent and parallel to an early Tertiary hinge belt. The two major oil fields are located on a local anomaly which was positive during Cretaceous time and received only a thin veneer of basal Tertiary (pre-Hemlock) sediments. The Tertiary crudes were probably generated from Eocene marginal marine strata or from upper Cretaceous marine shales which are unconformably overlain by the Tertiary sediments.

Significant quantities of gas, predominantly methane, are present in the loosely consolidated sands of the upper Kenai formation. The two conditions necessary for gas accumulation anywhere in the basin are (1) abundance of organic beds (lignite or coal) in the section (source rocks) and (2) a suitable trap.

GEOTHERMAL STUDIES AT OGOTORUK CREEK, AEC PROJECT CHARIOT TEST SITE, NORTHWESTERN ALASKA

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U. S. Geological Survey, Menlo Park, Calif.

Temperature measurements to depths of about 500 feet have been made in bore holes at the Project Chariot Test Site at Ogotoruk Creek on the northwestern coast of Alaska. Theoretical analysis of these data suggests a post-Pleistocene marine transgression, recent lagoon filling, and an increase in mean ground-surface temperature of about 1°C. in the past half century. Extrapolation of temperature profiles yields a local inland permafrost depth of about 1200 feet and a mean annual ground-surface temperature between −5.5 and −6.0°C. Because the temperature disturbance caused by drilling is still appreciable (about 0.15°C. in April 1960) and because measurements have not yet been made in the critical 500- to 1000-foot depth interval, these conclusions should be considered tentative.

CRETACEOUS STRATA OF THE CAPE DOUGLAS AREA, ALASKA PENINSULA, ALASKA

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Cretaceous rocks crop out south of Kamishak Bay between the Kamishak River and the ridges immediately east of Douglas River. These rocks are believed to form a continuous belt of exposures from this area south to the Kaguyak Bay section; however, between the South Fork of the Kamishak River and the Big River they have not been readily recognized because of Tertiary volcanism and intrusion.

A Lower Cretaceous unit lies with apparent conformity on the Upper Jurassic Naknek formation. It consists dominantly of gray siltstones and thin beds of fine-grained sandstone with numerous foot-thick calcareous beds made up almost entirely of Belemnite and *Inoceramus* fragments. Because there are no definitive megafossils, the age determination of this unit has been based on good microfossil assemblages from three localities. The unit is approximately 600 feet thick near the headwaters of the South Fork of the Kamishak River. To the north, the unit is overlapped by Upper Cretaceous strata. Its persistence to the south is indicated by Hazzard's work at Cape Kaguyak.

Upper Cretaceous rocks rest with slight angular unconformity both on the Naknek formation and on the Lower Cretaceous. A maximum of 750 feet of Campanian fossiliferous marine sandstone and siltstone crops out between the Kamishak and Douglas rivers. More than 1300 feet of Campanian very fine-grained sandstone and dark-gray shale exposed in the ridges immediately east of the Douglas River are believed probably to overlie the Campanian beds exposed between the Kamishak and Douglas rivers. The Campanian rocks of the Douglas River area are probably the correlative of the portion of the lower half of the section exposed on the north side of Kaguyak Bay.

UNCONFORMITIES

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Unconformities are a convenient medium for subdivision of the stratigraphic column, yet they are arbitrary and varied in their significance. Classification of an unconformity is valid only for the place in which it is observed. Subaqueous unconformities are at least as numerous as subaerial and may extend toward and onto the land with gradually or irregularly widening hiatuses. Most unconformities cross the time boundary. The temporal value of an unconformity is valid only for the place of its observation. The same species or even the same assemblage of fossils may occur both below and above an unconformity. Any contact between two igneous bodies should be considered an unconformity *s. l.* Diagenesis, *s. l.*, may cause profound changes in the rocks at any time, more than once, and at any position in space. The boundary along which diagenesis acted may be wrongly interpreted as an unconformity. Diagenetic processes may obliterate any traces of unconformity.

MULTIPLE GLACIATION IN THE YUKON-TANANA UPLAND, ALASKA: A PHOTOGEOLOGIC INTERPRETATION

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At least two major alpine Quaternary glaciations are recognized in the Yukon-Tanana Upland of interior Alaska. The Upland, which has no glaciers today, is an area of rolling hills and low mountains with several peaks 4000 to 6000 feet above sea level. All peaks more than 4000 feet above sea level were glaciated. Approximately 3 per cent of the Upland has been glaciated; the glaciers were most extensive on the north-facing slopes.

The older glaciation is represented by U-shaped valleys and poorly preserved lateral and end moraines with no lakes or characteristic glacial microrelief. The cirques of this glaciation are not fresh, and the base of the north-facing cirques is approximately 4000 feet above sea level. Glaciers extended at least 15 miles from the peaks.

The younger glaciation is recognized by well-preserved, little-modified knob and kettle topography on well to fairly well preserved lake-pocked compound end moraines 5 to 8 miles from the cirques. The cirques are strikingly fresh, and many contain tarns. The average elevation of the north-facing cirque bases is approximately 4500 feet above sea level. In both glaciations many peaks bore only cirque glaciers.

The two major glacial advances are correlated with the Donnelly and Delta glaciations of the Delta River area to the south and are considered Wisconsin and pre-Wisconsin in age, respectively.

RECONNAISSANCE ENGINEERING GEOLOGY FOR HIGHWAY LOCATION IN ALASKA

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At the request of the Bureau of Public Roads, the U. S. Geological Survey has made reconnaissance engineering geologic studies of possible highway routes from Tanana to the Seward Peninsula and from Talkeetna to McGrath. Both proposed routes traverse regions in which road building would be difficult.

In parts of the Seward Peninsula and in the central part of Alaska thick deposits of water- and wind-laid silt, deposited largely as the result of Pleistocene glaciation in the mountains, blanket the lowlands and lower hills. This silt is perennially frozen and contains large ground-ice masses. When the insulating surface vegetation is disturbed, the ice melts, swamps develop, and thaw lakes may form. The fine sediments are also extremely susceptible to seasonal frost action. Moreover, the silt covers any coarser sediments, and material suitable for borrow is lacking. The silt-covered areas should be avoided, or routes across them should be held to a minimum and carefully limited to zones of best drainage. Road alignment in the Nulato Hills is a problem because structurally controlled ridges with as much as 1000 feet of relief trend across the desired direction of travel.

Between Talkeetna and McGrath in the Susitna River valley there are many bogs in the glaciated terrain that would necessitate special road foundations. In the Alaska Range there are narrow passes subject to mud flows, landslides, and snowslides; deep gorges and broad, many-channeled glacial rivers would have to be bridged.

ABSTRACTS OF PAPERS SUBMITTED FOR THE MEETING IN NEW YORK DECEMBER 27–30, 1960 (SECTION E, AAAS)

NONDESTRUCTIVE X-RAY SPECTROGRAPHIC ANALYSIS OF EXTRATERRESTRIAL SUBSTANCES

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X-ray spectroscopy as an analytical tool has unparalleled advantages in the analysis of extraterrestrial objects such as stony and iron meteorites, tektites, and impact substances. The methods of analysis are highly specific and nondestructive. The latter feature is particularly attractive in the analysis of specimens that are part of rare museum or private collections. Two such X-ray devices are described. The X-ray probe is a device using the X-ray fluorescence principle and has a resolution of 0.5 mm. This apparatus can be used to obtain analytical information on semimicroscopic substances (0.5 mm or larger) in place in meteorites simply and quickly.

The electron probe, which uses a focused electron beam for excitation, can be used to analyze selected areas as small as 10 microns in diameter. Such equipment has already been used to study iron–nickel ratios in various mineral phases in a weathered meteorite. Microscopic phases such as kamacite and taenite can be analyzed with ease. Results on the effects of weathering on the nickel content of meteorites are reported.

EXPERIMENTAL DRILLING IN DEEP WATER

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The planned drill hole to the Moho, at its minimum depth of 30,000 feet beneath the ocean surface, is about 20 per cent deeper than the deepest hole yet drilled on land. This drilling will be attempted in the world's most difficult environment—the deep ocean. It will require new means for positioning and maneuvering a ship. It will utilize new materials and methods of drilling and newly devised coring equipment. If successful, the project will retrieve continuous oriented cores in very soft and very hard rocks for some 15,000 feet.

All these things appear to be within the reach of present technology if our engineering capabilities are extended to their limit. As a first step a test program has been planned which, in terms of difficulty, lies midway between our present capabilities for coring the sea floor and the eventual Mohole.

In the near future, AMSOC expects to drill, log, and core several holes about 1000 feet into the sea bottom in water 12,000 feet deep. On the basis of oceanographic studies, a site has been selected in the vicinity of Guadalupe Island off the Mexican coast. The preliminary operations should reveal the possibilities and limitations of various ship-positioning systems. They should also enable us to determine the capabilities of laterally unsupported drill pipe subjected to the stresses imposed by oceanic conditions. Using a specially designed wire-line core barrel we will attempt to obtain continuous cores of the entire sedimentary section beneath the ocean. If the venture is successful, it will demonstrate how sediment drilling can be done beneath the ocean with existing equipment, and it will produce the data needed to design the ultimate ship.

HEXAGONAL STALACTITE FROM RUSHMORE CAVE, SOUTH DAKOTA

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A stalactite having the form of a hexagonal prism was found in Rushmore Cave near Rapid City, South Dakota. It is about 5 inches long and half an inch across. The broken end is a perfect cleavage plane inclined to the axis of the stalactite indicating that the stalactite is solid and is a single crystal of calcite. The cleavage surface also reveals concentric growth rings. The hexagonal stalactite occurs

in the midst of hundreds of normal stalactites having tapered forms and nearly circular cross sections. Evidence indicates that it is a true dripstone speleothem and was not submerged when it crystallized. The following conditions are believed to be necessary for the formation of a stalactite having external crystal form: (1) growth from a seed crystal having its c axis vertical, (2) deposition at a sufficiently slow rate to permit continuous crystallization.

In this case the seed crystal may very well have been a "soda straw" stalactite. The uniform diameter particularly suggests this.

DRILLING FROM FLOATING VESSELS IN THE OPEN SEA

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Prior to 1956, offshore drilling was conducted from fixed or mobile platforms, all of which took their support from the sea floor. Since that time, the necessity to work in water depths of 100 feet or more, and the need for cheaper offshore drilling methods in order to make offshore oil competitive in today's market, has led to the development of heavy floating drilling equipment. This equipment has been used to drill in water depths up to 360 feet in open-sea areas. Some of the special facets of the design of this equipment are a derrick, especially designed for torsional and whip loads, an automatic, all-weather drill-string handling system, a sea-floor foundation to support the well head and casing strings, a high-strength flexible anchor system, and a flexible and removable connection between the well head and the vessel.

Definitive engineering work is now being conducted to prepare the Cuss I drilling vessel to do some experimental drilling in 12,000 feet of water preparatory to drilling the Mohole. Some of the unique features of this project will be dynamic position control of the vessel with surface-propulsion units, guides to control drill-string stress, and a specially designed high-strength drill string. Successful completion of this operation will contribute greatly to the progress of oceanic engineering and scientific projects now being planned.

MAKING OF A MODEL MOON

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The method and techniques are described in development of a scale model of the moon, which is a part of the AAAS exhibition. To portray the moon's surface, an analysis was made of 5000 surface features, leading to a theory on the origin of lunar topography.

WATER RESOURCES OF THE TRANSVAAL FOR INDUSTRIAL DEVELOPMENT

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In a country like the Union of South Africa, which is poorly endowed with water resources, the proper use of water is of the utmost importance. Its availability, purity, and cost are limiting factors in the distribution and growth of population and industry.

Agriculture is the major consumer of water in the Transvaal, and it is an expensive consumer. For each ton of rye grown, more than 600,000 gallons is used, for a ton of corn 400,000. Put another way, for each pound of national income derived from agriculture, 28 gallons of water is consumed, while for each pound added by manufacturing only 1 gallon is used.

Because of historical and political circumstances agriculture has been allowed to expand its share of the steady (*i.e.*, for 70 out of 100 years) available water to the extent that industrial development in the Southern Transvaal will very shortly have to curtail its expansion. The government wants to decentralize industry to remove what they consider an overcentralization (about 55 per cent of the Union's manufacturing establishments) and to foster aparthied. It would be a sounder economic policy to change the fixed demands of the irrigation developments to a flexible policy of extensive irrigation.

At present there is no other area in the Transvaal that offers any but raw-material oriented plants, an economic incentive to locate outside the Witwatersrand area. Not only do the gold mines on the Reef constitute the Union's major market, but they are the only area in the Transvaal except for a small isolated area that is adequately supplied with water resources. All the rest suffers from a lack of perennial rivers, high evaporation rates (more than 50 inches), and generally poor ground water.

PROGRAM PLANNING FOR FORESTS—NEEDS AND TECHNIQUES

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Planning a sound and co-ordinated program of activities on forest lands requires the following steps: (1) collection of the basic facts on forest resource conditions and needs, (2) interpretation of the facts, (3) determination of resource potentials, (4) determination of prospective demand.

These procedures make possible the establishment of objectives and goals. The principles have been used in the U. S. Forest Service's recent Timber Resource Review and in the development of a multiple-use program for the Natural Forests ("Operation Multiple Use"), and are at present being followed in the national forest recreation survey and conservation program for America's small forests. The writer discusses the development and utilization of these principles.

NEWARK, NEW JERSEY: A CASE STUDY IN URBAN RENEWAL

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Rebuilding the American city has become as politically popular as heaven, home, and mother. The greatest political, economic, and social phenomena of twentieth century America are the problems related to urbanization caused by great population growth and massive technological change in our industrial economy. The American city is no longer a "melting pot"—it is a "pressure cooker".

The objectives of (1) modernization of obsolescent plant—residential, commercial, industrial, and transportation; (2) attraction of new ratables; and (3) creation of new jobs have fused the efforts and energies of the corporate citizens of government, business, and labor in redeveloping Newark, New Jersey.

In the modern city each major program depends on the equivalent success of all the rest. The "big idea" in Newark has been the creation of a spirit of genuine partnership among businessmen, labor leaders, and politicians. The war against slums in Newark is being fought on all fronts at the same time—through the formation of the Newark Economic Development Committee and other civic and public agencies and has culminated in great national and international interest in the "new" Newark. National, state, and local leaders are increasingly concerned with the interweaving of technological advancements with the economic sinews and the political and cultural needs of Newark's metropolitan region (the fourth most important industrial market in the United States).

As an experimental laboratory at the urban frontier, Newark has become one of the foremost case histories in the effort to conquer and control "inner space".

PALYNOLOGY, PALEOFLORAS, AND PALEOENVIRONMENTS

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Fossil polospores in Quaternary sediments relate directly to modern plant types. Thus floral assemblages and environments may be reconstructed for Pleistocene and post-Pleistocene polleniferous sediments.

Pre-Pleistocene palynologic types are less amenable to this approach. With increasing antiquity, biologically valid taxonomic assignments of fossil polospores are possible only to broadly equivalent modern taxa. Because of this, their interpretive value is limited in terms of modern counterparts.

In the older sediments, paleofloral and environmental interpretation based on polospore analysis must be more generalized.

Biotic diversity has been interpreted as a product of evolution, dependent upon the length of time through which a given biota has developed in an uninterrupted fashion.

Changes in diversity of fossil polospore assemblages, traced through sedimentary series, are interpreted as having evolutionary and environmental significance in terms of the floras that produced them. Congruent changes in the frequency of first and last appearances lend support to these hypotheses. Paleobotanical remains and the physical history of the region as deciphered directly from the sediments are other sources of supportive evidence.

Data from three publications dealing with the description and stratigraphic distribution of fossil polospores are analyzed by this approach, to exemplify the above: the first is concerned with the Lower Cretaceous through the Tertiary of Central Europe; the second with the Upper Paleozoic (Permo-Carboniferous) of Europe, Eurasia, and North America; and the third with the Precambrian, Infra-Cambrian, and Lower Paleozoic Pre-Baltic area of Russia.

ARAGONITE-CALCITE PROBLEM

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Aragonite is about 11 per cent more soluble than calcite, and, therefore, both are stable during precipitation when the supersaturation with respect to calcite affects this value. Under this condition it is the relative rates of crystal growth and crystal nucleation that determine which polymorph will occur. The literature reports how temperature, many trace substances, and rate of precipitation may be responsible for aragonite deposition in vivo and, at high or low supersaturation, in vitro. Nevertheless there is essentially no information available on the mechanisms of nucleation and growth for these polymorphs. It is postulated here that growth is upon screw dislocations in either case, and the known effects of contaminants (other than epitaxis), temperature, and rate of precipitation are related to hypothetical, but likely, interactions with the formation, maintenance, or blocking of screw dislocations on the growing surface. In this view, Sr^{++} induces the precipitation of aragonite by forming an isomorphous crystal, while Mg^{++}, SO_4^{--}, and perhaps other ions by inducing dislocations in the aragonite lattice; and temperature by affecting the availability of other ions or by inhibiting calcite nucleation over dislocations. The common occurrence of strontium in natural aragonite is believed to reflect its higher solubility in this lattice rather than its contribution to lattice stability. Aragonite probably occurs more frequently in caves than presently believed.

PLEISTOCENE PALYNOLOGY IN THE UNITED STATES

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Pollen analysis consists of the identification and tabulation of pollen and spores preserved in sediments. One objective of the technique is to study the vegetation and climate of the past, on the assumption that the percentages of pollen in sediments reflect the relative abundance of species in the surrounding vegetation. Another objective is to develop regional pollen chronologies for use in dating pollen-bearing sediments and underlying deposits. The recent trend to investigate each site in great detail, using more refined techniques, has led to the increased application of pollen analysis to stratigraphic problems. However, pollen analysts often disagree on the vegetational and climatic interpretations given to pollen sequences. An obvious difficulty is the lack of information about the present distribution and ecology of plant species. The primary difficulty in interpreting pollen diagrams, however, stems from our failure to investigate the ways in which the abundance of plant species will affect the percentages of pollen deposited in sediments. Many of the sources of error that have been recognized by European workers are made far more acute in this country by the large number of species represented by each generic pollen type, and by the disparity among species in efficiencies

of pollen production and dispersal. Both the paleoecologic and stratigraphic value of pollen data will depend on the amount of research devoted to these theoretical problems.

VREDEFORT RING STRUCTURE: AN ASTROBLEME (METEORITE IMPACT STRUCTURE)

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In response to a request for a search, R. B. Hargraves (Witwatersrand University) has discovered shatter cones (world locality No. 9) extensively developed in the quartzites and granites of the Vredefort ring structure or "dome" of South Africa. Shatter cones demonstrate that this huge deformation was invaded by intense shock waves; hence it must be an "astrobleme"—*i.e.*, an ancient asteroid impact scar, as Boon and Albritton, and Daly have suggested. The Vredefort ring consists of a 40-km diameter circular collar of steeply upturned or overturned Precambrian sediments (the presumed impact crater) some 13,000 m in stratigraphic thickness surrounding a shattered "throat" or plug of nonintrusive granite. All this is surrounded by a ring syncline with a total diameter of 200 km.

Explanation of the ring in terms of cryptovolcanism or conventional tectonism appears untenable. Instead, a review of the problem suggests: (1) an asteroid impact in late Precambrian or early Paleozoic with a kinetic energy of 1.6 million megatons TNT equivalent (based on scaling up from nuclear crater Teapot ESS using a scaling factor of [weight of explosive]$^{1/2.4}$); (2) the blowing out of a crater with a peeled-back collar some 40 km across and more than 13 km deep and the formation of the annular syncline; (3) shock-induced shatter coning and thermal and pressure metamorphism in the collar; (4) formation of the pseudo-tachylite as a shock-induced fusion product at pressures above 10^6 bars; (5) formation of the basic granophyre dikes from the fused rock lining the crater cavity. Finally, the central granite plug resulted from isostatic uplift (assisted by elastic recoil?); its 530-square-mile area is several times larger than the minimum area for isostatic compensation. At Vredefort an impact explosion occurred comparable to the formation of Copernicus or Tycho on the moon.

POSSIBILITIES OF WIRE-LINE LOGGING METHODS IN THE MOHOLE

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In wire-line well logging, physical characteristics of subsurface strata are measured by means of sensing devices (sondes) lowered into a drill hole on logging cable. The suitability of available equipment for logging the Mohole is reviewed, since greater depths, and possibly greater down-hole temperatures, will be encountered than in wells heretofore logged. Measurements of logging depth from the platform of a floating ship in open sea will be facilitated by use of radioactive depth markers; suggestions have also been made for ship's-motion compensation.

The availability, utility, and possible developments of logging measurements of geophysical and geological interest are discussed: sonic-compression wave velocity is measurable either by a sonic velocity log or with two in-hole geophones with surface explosives. *In situ* density can be measured with a gamma-gamma log. Radioactivity measurements include natural gamma-ray and neutron logs, as well as gamma-gamma and spectral logs. Electrical logs include spontaneous potential and resistivity measurements. Magnetic measurements include bore-hole magnetometry, susceptibility logs, and magnetic field-direction measurements. Thermal measurements include thermal conductivity and bore-hole temperature.

In-hole identification of them discontinuity will likely be through changes in density and sonic velocity. The possibilities of deriving formation porosities and permeabilities from log data are discussed.

The proposed use of the logging cable for the taking of oriented cores is mentioned.

RECENT TRENDS IN MARINE GEOPHYSICAL EXPLORATION

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During the last 10 years many new techniques have become available for exploration of the water-covered areas of the world. Some of these were adaptations of existing techniques to the marine environment; others have been developed exclusively for marine use. In addition, improved methods of evaluating and computing data have been devised which allow more detailed analysis than was previously possible.

A number of these new developments are described, and examples are presented of their application to marine exploration.

APPLICATION OF CENSUS STATISTICS TO PROBLEMS OF URBAN RENEWAL

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Census statistics have long played an important role in the planning of urban-renewal programs. Although relatively few detailed statistics are yet available from the 1960 Censuses of Population and Housing, we know that changes have been large and their impact has differed enormously from area to area. Since 1950, 80 per cent of the nation's population growth has taken place in our standard metropolitan statistical areas; the rate of growth in the central cities (8 per cent) was only one-sixth as great as that in the adjoining rings. A large number of central cities declined in population between 1950 and 1960. A detailed examination of the patterns of growth and decline during the past decade will provide information of much value to urban planners.

Among the important features of the 1960 Censuses of Population and Housing are the speed-up of the results, the addition of a number of new questions, and an increase in the number of small areas for which data will be presented. The use of electronic equipment is expected to yield results 6 to 18 months earlier than 10 years ago, and to make possible great flexibility in the devising of special tabulations. New information on housing includes the provision of a third category on condition—deteriorating—a category intermediate between sound and dilapidated. Information on duration of occupancy, on number of bathrooms, and presence of a basement may also prove of considerable value. New data on place of work and means of transportation to work will make possible a much better understanding of the patterns of transportation.

The new information, when combined with the continuing housing statistics, should provide a good statistical base for studies of urban renewal.

The services of the Bureau are not restricted to published information. Special tabulations, tailored to the needs of a specific area, can be provided at cost.

SEDIMENTS FROM ARGENTINE CONTINENTAL SHELF: PRELIMINARY REPORT

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The oceanographic research vessel VEMA of the Lamont Geological Observatory made four cruises to the South Atlantic during the years 1957–1960. Over the period of these cruises, about 90 piston cores of the Argentine continental-shelf sediments were obtained from the estuary of the Rio de la Plata to south of Cape Horn. The sediments of these cores, which average several meters in length, provide a record of Recent and Late Pleistocene geological events.

Most of these cores have been examined megascopically, and a few selected cores have been analyzed in detail. From the Rio de la Plata to about 50° S. Lat. the sediments consist of sand underlain by a distinct layer of shell. This shell layer was apparently deposited during an advance of the sea across the continental shelf as sea level rose after the latest glacial period. An attempt has been made to date this event by both paleontological and carbon-14 methods.

South of the Straits of Magellan the sediment below the surface layer of sand consists of gravel or

a mixture of shell and gravel. This layer is thought to be equivalent to the shell layer farther north. More extensive glaciation in the region of Tierra del Fuego, and closer proximity of the glaciers to the coast, offer possible explanations for the increase in pebble content.

CONVERGENCE OF EVIDENCE ON CLIMATIC CHANGE AND ICE AGES

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Quantitative paleoclimatology opens a new frontier in earth science. Time parameters are provided by radiocarbon dating, by reappraisal of de Geer's varve chronology, by correlation with palynology and paleontological analysis, and by geochemical work on deep-sea cores. Climatic means (temperature, precipitation, etc.) are provided by oxygen-isotope studies, paleobotany, and pedology. Preliminary conclusions indicate that "ice ages" are produced by normal variations in observed solar-controlled meteorological effects, which are reinforced, probably aperiodically in geologic time, by topographic "accidents".

Long-term meteorological and historical records disclose multiple cycles, *e.g.*, 11-, 22-, 40-, 80-, 189-, 567-year periods, in part related to sunspots, geomagnetic phenomena, and planetary motions. Mean annual temperatures in temperate belts vary 2–3° C.; the longer the period, the greater the effect in terms of snowfield accumulation or glacier-ice melting. This concerns the world hydrologic balance and thus is reflected on world tide gauges. However, while accumulation advances directly in short steps, melting shows marked retardation.

Major astronomic cycles, such as the precession of the equinoxes, with periods of 21,000, 40,000 and 92,000 years, control absolute and hemispheric variations in effective solar radiation. Although exaggerated by Milankovitch, mid-latitude temperatures will vary 3–5° C., but mainly in the northern hemisphere which contains 95 per cent of the world's "sensitive" mountain glaciers. Cyclicity of major climatic change is controlled thus by the northern hemisphere's topographic "accidents" (high mountains, broad continents).

Paleomagnetic data (Runcorn *et al.*) show secular polar migration through geologic history. Coincidence of poles with mountainous continents must initiate abnormal world-wide cooling, lowered snow lines, negative eustasy, and increased continentality. Such conditions are reinforced by mountain building, and further negative eustasy by oceanic-trough deepening. Oceanic currents may be blocked as in Middle East and Panama during the mid-Tertiary; from then until early Quaternary the mid-latitude temperatures dropped by 10–12° C.

The earth will remain relatively cool while Antarctica lies symmetrically about the South Pole. However, temperate belts will continue to be alternately glaciated and deglaciated every 40,000 to 90,000 years.

APPLICATION OF GEOLOGY TO MAN'S SURVIVAL ON THE MOON

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The application of geology, geophysics, and geochemistry to man's survival on the moon is fivefold: (1) A knowledge and interpretation of terrain features of volcanic or impacted areas will enable their utilization for protection and concealment; volcanic landforms offer more terrain advantages than do impacted landforms. (2) Optimum use of surface rocks for insulation material, building stone, and water content will be implemented by geological mapping and evaluation. Meteoritic rocks offer fewer advantages than do volcanic rocks in providing for these needs. (3) The mineralogy of a volcanic terrain may provide critical elements such as sulfur or ice needed for technology and survival. Meteorites offer iron and nickel as easily obtained by-products. (4) The use of heat and power, whatever the degree available, may be more expediently provided by geological prospecting. Thermal sources on the moon may be radioactive surface rocks, potentially active hot spring and fumarolic zones, and the ray systems and their intersections. Chondrites offer relatively few prospects for radio-

active heat sources. (5) The geoscientist may be able to prescribe the optimum tools specific for the exploration needs of the first men on the moon. For example, the neutron-neutron logger is specifically for the detection of water, and the neutron-gamma DT accelerator logger for chlorine or sulfur. The meaning of lunar exploration, however, should not be relegated just to keeping a man alive there. It should provide the means for man's survival for understanding many natural phenomena. He may learn of the early history of the earth's crust by studying the lunar crust, or even the composition of pre-life sea water that could conceivably exist on the moon. Finally we want to know from the man on the moon if meteoritic impact or defluidization is a generally operative cosmogenic process.

MEASUREMENT AND EXPRESSION OF AGRICULTURAL INTENSITY

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The study of agricultural intensity distribution has always been of interest to geographers, but most effort in this direction has been for purposes other than the outlining of intensity patterns as such. Yet, a knowledge of intensity distribution is now more important than ever, since the greatest changes now occurring in agriculture are those of intensity, not the additions of new land.

Many reasons account for the surprisingly small amount of geographic work done specifically on agricultural intensity. Measurement problems, particularly those associated with the inadequacy of definitions for labor, capital, and acre yields as they bear on statistical analysis, remain to be solved. Problems of intensity expression, such as the unit to be used and its associated difficulties of value conversions and availability and uniformity of statistics, must also be faced.

Nevertheless, intensity patterns do exist, and the means for their discovery and mapping are increasing. In this study, value of farm production, capital expenditures, and "value added" for each major agricultural region of California are related to their crop areas; the resulting ratios provide three intensity patterns: *production*—or *yield*—intensity; *capital* (including labor) intensity; and *gainful* intensity. Although tentative and subject to qualifications, the differences between the conventional production pattern of the state and those of intensity are great enough at least to justify further efforts in pure intensity research. Especially interesting findings are that both coastal southern California and the small desert oases far surpass the leading agricultural producer, the San Joaquin Valley, in overall intensity.

MOON-MAPPING PROGRAM AT ARMY MAP SERVICE

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The Army Map Service is making a 1:5,000,000 map of the moon. The map will be compiled from measurements made on a three-dimensional model of the moon formed by the projection of stereo pairs of lunar photographs. The stereo model is oriented and scaled by a set of finely determined control points that represent one feature in each of the 246 10° by 10° equal-area squares that cover the entire visible surface of the moon. The most accurate co-ordinates available, before the Army Map Service started this program, were for features that represented an area equal to only about one-third of the visible surface of the moon and have uncertainties of ±2100 feet in the horizontal co-ordinates.

UNITY OF PURPOSE IN THE EARTH SCIENCES

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Webster's definition of Geology as, "The science which treats of *the history* of the earth and its life", is unduly restrictive. Etymologically more correct is the simple definition, "The science of the earth", and preferable would be, "The science which treats of *the constitution* of the earth".

Viewing the earth as a continuum, from innermost core to outermost atmosphere, the science is a compound of "ologies", whose disciples are truly geologists in that their specialized approaches all focus on the constitution of the earth. While some paradoxes remain, broad acceptance of this concept will: (1) dispense with the clumsy anglicization, "Earth Sciences"; (2) consolidate the spirit of co-operation among the many branches of geology; (3) unify the objectives of a large number of scientists, who collectively represent a most versatile and imaginative field of Science in their endeavors to break through the frontiers of knowledge.

SCIENTIFIC OBJECTIVES OF THE MOHOLE AND A PREDICTED SECTION

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The major scientific objective of the AMSOC project is to obtain samples of the upper part of the earth's mantle and to determine the nature of the M discontinuity. Boisse's analogy of 1850 suggesting that meteorites were a fair approximation of the composition of the earth's interior was a brilliant idea for its day but is too inexact for present purposes.

Above the discontinuity is a layer commonly called the "crust" and generally considered to be basalt. It is extraordinarily uniform in thickness, suggesting that its base represents a phase transition and that the discontinuity under the oceans might represent the level of some isotherm, or past isotherm, at which a reaction took place.

Above the "crust" is a layer of variable thickness and seismic velocity thought to be consolidated sedimentary or volcanic rocks. Finally one comes to the unconsolidated sediments of the ocean floor, which are a few hundred meters thick and no doubt resemble the material obtained from shallow cores. In these last two layers one might hope to find fossils going far back in the history of the oceans and to derive from this record information of extraordinary scientific importance.

The following predictions are made:

(1) The mantle will be peridotite resembling the olivine nodules found in basaltic volcanoes and St. Paul's Rock.

(2) The "basalt crust" will be serpentinized peridotite, hydrated mantle material.

(3) The M discontinuity represents a past isotherm above which serpentine was a stable phase.

(4) The sedimentary column will be very incomplete and have many great hiatuses.

POSTGLACIAL ENVIRONMENTAL CHANGES IN THE LAGUNA SAN RAFAEL AREA, SOUTHERN CHILE

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A sequence of environments spanning at least the last 7000 years is interpreted from pollen profiles of radiocarbon-dated peat deposits in the vicinity of Laguna San Rafael, Province of Aisén (*ca.* 46°40'S., 74°00'W.). Stratigraphic samples were removed from these deposits for study as part of the research program of the American Geographical Society's Southern Chile Expedition 1959, carried out under Office of Naval Research contract.

An interval of relatively warm and dry climate began close to 6500 B. P. and lasted probably until *ca.* 2500 B. P. A gap in the record between *ca.* 5000 and 4000 B. P. appears to be identified with a transitory episode of greater moisture, possibly accompanied by a temperature decrease. For some time prior to 6500 B. P. climate was more humid. The last two or three millennia have witnessed a lowering of temperature coupled with rising humidity. Volcanism (presumably associated with Monte

Macá, 185 km north of the laguna) has occurred regionally within the last 1000 years, and crustal movement has taken place locally during recent centuries.

This interpretation of the environmental sequence suffers somewhat from the limited data at hand concerning the autecology of the plants forming the laguna rain forest. *Weinmannia* is found to be the best indicator of relatively greater warmth and dryness in the past than at present. *Podocarpus* and *Tepualia* are indicative of paludification and along with *Nothofagus* are consonant with rising humidity and comparative coolness. Plant successions resulting from deglaciation are recognized by the presence of *Gunnera*, Ericales, Compositae, and the Filicales in the basal fractions of the peat deposits.

AIRBORNE EXPLORATION METHODS

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Just as basic research normally suffers in wartime, while all energy and manpower is spent in development, so oil and mineral exploration suffered during World War II, and most energy was spent in exploiting known deposits. Thus the wartime exploration vacuum, the pressure to repair the ravages of war, and the very obvious future population pressure all combined to create an exceptionally high level of post-war exploration activity.

This strong demand for pertinent information over vast areas created a natural market for the airborne magnetometer; the demand for uranium brought on a requirement for the airborne scintillometer; the concomitant research into other possible airborne methods led to several varieties of airborne electromagnetic instrumentation. In the last 2 years successful airborne surveys have been made measuring variation of the earth's gravity field and of the earth's natural electromagnetic field.

Other airborne geophysical instrumentation, not directly applicable to exploration, includes the airborne profile recorder, the three-component airborne magnetometer, the positioning systems, such as doppler radar, Shoran (for line-of-sight horizontal positioning), and Decca, Lorac, Raydist, and Loran (for non-line-of-sight horizontal positioning).

The last decade has also included the broad development of the art of air-photo interpretation, encouraged by the increasingly easy availability of good air photos of much of the earth's surface.

Airborne exploration has now become a steady but increasingly complex activity with a fast-moving pattern, involving aircraft from the flying-laboratory type, such as B-17's, to the smallest plane capable of carrying a pilot and a few pounds of instrumentation, and resulting in surveys to date in more than 70 countries.

VOJVODINA (YUGOSLAVIA), A STUDY IN AGRICULTURAL EVOLUTION SINCE 1945

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Yugoslavia's principal agricultural region, its breadbasket, is the Vojvodina, located in the southern part of the Panonian Basin, between the Danube, Tisa, and lower Sava rivers. It is a region of fluvial and aeolian accumulated materials and the isolated massif of the Fruška Gora.

The Vojvodina occupies 8.5 per cent of the total land area of Yugoslavia and has a population of more than 1.8 million people. Twenty per cent of Yugoslavia's arable land is located here, where in 1959 more than 31 per cent of Yugoslavia's wheat, 38 per cent of its maize, and more than 55 per cent of its sugar beets were produced.

As a result of World War II, new political conditions and new ownership relations were introduced. While the post-war drive for collectivization had reached its height by 1950, in 1959, 37 per cent of all agricultural land was still worked by state farms or in collaboration with private farmers. These figures are much above the Yugoslav average but indicate the agricultural importance of this region to the whole country.

Because of its economic importance to Yugoslavia, special attention has been given to increasing

its agricultural production. The paper reviews the methods used in increasing production and analyzes future trends and needs—*e.g.*, the need for an alternating cropping pattern, the impact of the 500-km-long Danube-Tisa-Danube Canal now being built, and the introduction of modern agrotechnical methods. The land-use pattern and production changes are illustrated with maps. Colored slides taken during the author's two recent field visits present a picture of the slow but consistent evolution in this vital region.

INTERNATIONAL CO-OPERATION AT SEA

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Oceanography is experiencing two new and important stimulations. Experience gained during the International Geophysical Year convinced research-ship operators all over the world that international co-operation in marine science is not only practical but highly productive. A 10-nation survey of the Indian Ocean has been agreed to as the next major effort.

It is also evident that there is an increasing demand for oceanographic forecasts of various kinds. The bottleneck in most types of ocean predictions is the weather forecast. However, if a data-gathering network were established at sea, the chances are good that meteorology would benefit. Anchored radio telemetering buoys now under development give promise of providing the sorts of continuous information that would permit useful marine forecasts to be made. Already ice forecasts, and the routing of ships to take advantage of currents and to avoid head seas, have saved time and money. Suitable predictions could be used to advantage in the fishing industry and in naval operations.

An ocean-wide prediction service will require the same sort of international co-operation that has been developed in weather forecasting.

CONTRIBUTION OF RUSSIAN GEOGRAPHY TO A SYSTEM OF PHYSICAL-GEOGRAPHICAL REGIONS

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For a number of reasons, the study of the physical elements of the earth's surface has long dominated Russian geographical science. A stated basic objective of this study has been the preparation of a system of physical-geographical regions not only of Russia or the Soviet Union but of the earth as a whole. Physical-geographical regionalization has two dimensions, at least, Russian geography maintains. One involves, besides cognition, a contribution to knowledge of a scientific theoretical nature. The other, and this of course may have more value in a planned economy, may serve in a practical way in the development of agricultural and other natural resources.

This paper reviews the contributions of Russian geographers, especially since the Bolshevik Revolution, to the literature on physical geographical regionalization.

TRENDS IN GEOGRAPHIC RESEARCH

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The main stream of geographic scholarship since Humboldt and Ritter has been devoted to the study of the significance of the areal arrangements and associations of things on the face of the earth. Some scholars have approached this purpose by examining particular processes of change as they operate in specific places; others have studied a variety of associated processes in a particular area. In any case geographic scholarship has focused attention on places. This main stream of geographic scholarship has been described and critically examined in English by Richard Hartshorne in two important publications (*The Nature of Geography*, 1939; and *Perspectives on the Nature of Geography*, 1959).

It follows that there are two ways for the individual geographer to specialize. Actually most geographers are specialists in the analysis of specific processes as they operate in particular places. Since World War II much attention has been devoted to the selection of data for geographic analysis and to the increased precision of observation and measurement. Cartographic analysis plays an always more important role in research. New statistical procedures are being developed to describe more precisely the areal association and causal connections of phenomena. Geographers are more and more concerned with the movements that flow from one area to another. Much attention has been given to the analysis of the viability of States and to the bases of national power. Physical geographers have been concerned with the measurement of water balance and the definition of terrain types. The unity of the field is given, not by the subjects studied, but by the purposes, methods, and basic concepts of geographic scholarship.

CHANGING PANORAMA OF PETROLEUM EXPLORATION

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Rapid post-war expansion has involved large numbers of organizations and nationalities in the world-wide search for oil. Its extension into vast virgin territories, often in previously inaccessible marine, desert, or arctic environments, graphically illustrates progress in petroleum exploration.

Modern oil exploration utilizes a fund of knowledge derived from past experience and the progressive application of science. Regional analyses of stratigraphy and tectonics, relatively new in the mature state of domestic exploration, are heavily stressed at all stages of foreign work and usually precede decisions to explore new areas. War-stimulated development of airborne reconnaissance methods has provided valuable aids in this respect. When exploration permits are granted, all locally suitable geological and geophysical methods are employed to develop an overall picture of the region's geological constitution and evolution, to the scale required for conclusive testing.

It is difficult to visualize radically new methods of smashing the barriers confronting the oil finder. Incessant in demanding aids, he is insatiably curious and innately resourceful and optimistic, ever ready to instigate and utilize research in diverse fields in governmental, collegiate, and commercial laboratories. Fertile fields include: broad studies of the constitution of the earth; improved instrumentation, technique, and data processing in geophysical methods; paleontological and palymological studies relating to chronology and ecology; radioactive geochronometry; geochemistry; and sedimentology. Also important is encouragement of sound basic training, realistic optimism, and a fine balance of determination and stubbornness with adaptability.

RESOURCES OF THE SEA

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Exploitation of the natural resources of the sea is concentrated along the continental shelf, which constitutes less than 8 per cent of the marine area of the earth. Deeper parts of the ocean, although largely unexplored, seemingly have far less potential than shallower marine areas. Mineral resources of the continental shelf are similar to those found on land, but their removal is complicated and made expensive by the water cover. Economically recoverable materials include oil and gas, sulfur, iron, and coal. Minerals eroded from land may be concentrated along beaches by the sorting action of waves and currents. Present-day recovery of these minerals is principally from ancient raised beaches, but submarine deposits await discovery and exploitation. Large quantities of chemical substances in sea water are presently unavailable because of the lack of economic concentrating processes. Magnesium, bromine, and whole salt are now being removed from the sea on competitive basis. Marine deposits consisting largely of the lime shells of marine invertebrates are used as a raw material by the chemical, cement, and building industries.

Food products derived from the sea amount to about 26.3 million metric tons a year. As human

populations expand, creating a larger food demand and crowding farm areas, the seas will supply an ever-increasing percentage of world food. The ultimate potential harvest that may be expected from the sea is unknown. Harvesting of plankton and farming of marine plants are essentially in the "accumulation of data" stage of development. Fishery techniques used in the catching of fish and gathering of shellfish are at a primitive level when compared with modern breeding techniques used in animal husbandry on land.

GEOCHRONOMETRY BY RADIOACTIVE DECAY

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Geologists have always recognized the importance of time in geological processes. Fortunately nature has provided several naturally radioactive nuclides which serve as potential time indicators. The most useful of these are C^{14}, K^{40}, Rb^{87}, Th^{232}, U^{235} and U^{238}. The decay constants of these species are known with sufficient accuracy, and the basic assumptions underlying the various age methods have been tested. With these dating techniques, all rocks older than Pleistocene (older than 1 million years) or younger than about 3×10^4 years may be reliably dated. Improved instrumentation will narrow this small gap.

Current researches in geochronology are following several lines: (1) the development of an absolute time scale, (2) the improvement of techniques and instrumentation, (3) expansion of the range of application of the various methods, (4) quantitative studies of the processes giving rise to occasional "discordant" ages.

The real challenge of this new tool lies in its successful application to the solution of geologic problems. Radioactivity age determinations offer assistance in the solution of problems ranging in scope from minute field relations to the origin of continents. They can be applied to problems as theoretical as the origin of granite or as practical as mineral exploration. Great strides are now being made toward adequate Precambrian correlations. A better understanding of the mechanics of orogeny is developing. Other applications in all fields of geology are readily imagined.

NORTHWESTERN CANADIAN SHIELD—A GEOGRAPHIC STUDY WITH SPECIAL REFERENCE TO MINERAL RESOURCES AND INDUSTRIES

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This region is bounded by Hudson Bay and arctic waters on the east and north, the Shield-Great Plains contact on the west, and by the fifty-ninth parallel on the south, an economic-geographic line beyond which no roads or railroads penetrate to connect the Northwestern Shield with the rest of Canada.

Climate, topography, vegetation, vastness, and inaccessibility all serve as physical deterrents to penetration and development. The area was crisscrossed by various groups of people for 4 centuries, but it was not until the past 30 years that any significant development occurred. The advent of aviation was largely responsible for opening up much of this remote region, rendering it accessible to prospectors and mining companies.

The physical geography precludes almost any economic activity other than mining. Uranium, gold, and nickel are being extracted at present, and encouraging prospects of various base metals have been found.

The keynote to growth and development here is transportation. Water transportation is available only 3 months of the year; aircraft provide the only other means, and at costly rates. Equipment, supplies, and fuel must all be hauled in, ores and concentrates shipped out (to distant markets). Besides excessive transportation costs, the North poses other problems such as excessive heating and warehousing costs, construction and mining in permafrost, long periods of isolation, and need for special inducements to attract personnel.

Despite the inherently repelling nature of the site, mines have operated; they are subject to the same laws of comparative costs as elsewhere. Recent advances in technology have facilitated the profitable discovery, extraction, and treatment of northern minerals. It seems likely that mineral industries will continue to flourish here, but little else will.

GEOLOGIST'S ROLE IN SELENOLOGY

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Until recently the geologist has played only a minor role in evaluating the surface features and structural aspects of the moon. In the future, his opportunities and responsibilities for participating in lunar programs will be unlimited and rewarding particularly in the areas of petrology, structure, and interpretation of relief patterns. Lunar rocks must be classified, their types mapped, and their relative ages established. Regional as well as local fracture lineaments need be evaluated in terms of age, extent, relationship, and origin. To decipher adequately many of these problems the geologist must be cognizant of the fundamentals of physics, static and dynamic mechanics, physical chemistry, thermodynamics, and strength of materials. The time has come when he must remove his thinking from "off the ground" and onto a new and fascinating surface some 240,000 miles in Outer Space.

PROJECT MOHOLE

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AMSOC Committee of the National Academy of Sciences-National Research Council with the financial sponsorship of the National Science Foundation is planning to drill a test hole for scientific purposes through the earth's crust beneath the deep sea to the M discontinuity. Project MOHOLE is under the scientific guidance of AMSOC Committee and its panels.

Preliminary studies indicate that it is feasible to drill into the ocean floor with more or less conventional floating equipment over 12,000 to 15,000 feet of water. Further studies of the complex engineering problems imposed by the ocean on the drilling platform and the drill string have been made, and most of the problems have been solved to the committee's satisfaction. Refined studies on the behavior of 12,000 feet of rotating drill string in sea water are still in progress.

Two areas within reasonable distance from United States ports have been selected as possible drilling sites. One of these is in the vicinity of Guadalupe Island in the Pacific. The other lies to the north of San Juan, Puerto Rico, in the Atlantic. Both areas are promising because the depth to the mantle is between 9 and 9½ km below sea level. The choice between these areas for the major project of drilling through the crust still awaits a final decision from the Site Selection Panel.

Preliminary experimental drilling is planned in order to obtain additional engineering information on drilling in deep water. This includes practice with newly developed station-keeping techniques and the use of newly devised equipment for obtaining cores in unconsolidated or soft sediments. It is expected that the above phase of the project will take place early in 1961.

CURRENT PRACTICE AND TRENDS IN MINERAL EXPLORATION

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Finding new ore deposits currently depends more and more on the integration of geochemical and geophysical techniques with exploration geology. "Mineral showings" are essential but less important than the proper interpretation of the geology; incidentally, "mineral showings" now legally include geochemical and geophysical anomalies. The heavy emphasis in exploration geology is still on good geologic maps and cross sections, adequate sampling, and such studies of mineralogy and petrography as seem appropriate. Current trends are an increasing use of geochemical and geophysical explora-

tion, and of physical exploration such as drilling and trenching, outside the specific target areas as aids to mapping and to an understanding of structure; preliminary library studies of geology and economics of promising exploration areas; the testing of alteration and mineral-deposit theory by field studies and physical exploration; the development and use of airborne geophysical equipment for rapid coverage of suitable terrain as well as the use of very easily portable specialized geophysical equipment; and a rapid rise in the use of geochemical exploration techniques. In geophysics, interest is currently concentrating in cross-check methods such as the in-phase and out-of-phase electromagnetic and the induced polarization methods; also in the use of various radiation detectors, both with and without activation sources.

Geochemical exploration is using various inexpensive rapid methods of trace analysis to delimit areas of soil, bedrock, stream sediments, water, or plants in which certain elements differ significantly from their expected background value; proper interpretation of such anomalous areas is adding greatly to the world's reserves.

PALYNOLOGY AND PREHISTORY: THE SOUTHWEST AN EXAMPLE

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What can pollen stratigraphy reveal concerning past cultural events? In the American Southwest some of the major problems in prehistory concern the relationships between Early Man and the large extinct mammals, the impact of climate on culture, the appearance of agriculture, and the cause of a widespread population "crash" during and after the thirteenth century.

Within the Desert Grassland of southern Arizona the pollen record of flood-plain alluvium begins in early postglacial time, dated by carbon-14 at around 8000 years B.P. and associated with Sulphur Spring stage grinding tools of the archaic Cochise Culture. High NAP content of the pollen spectra shows that the climate was dry, equivalent to that of the present. A subsequent rise in pine pollen during the middle of the postglacial period suggests that the Altithermal was more moist, not drier than at present as is commonly thought.

Evidence of early corn cultivation associated with Chiricahua cultural remains appeared in flood-plain alluvium near Point of Pines. From about 4000 B.P. until about 700 years ago, corn cultivation increased in importance. Between the thirteenth century and the Spanish conquest an environmental change of unknown scope had made agriculture impossible in many areas formerly cultivated. At Mesa Verde a high frequency of *Cleome* pollen reveals its use as a prehistoric "starvation plant" before abandonment in the thirteenth century. Along the Pecos River in New Mexico agricultural people turned to bison hunting. At Point of Pines, Mesa Verde, and Glen Canyon, trees and shrubs reinvaded sites abandoned by Pueblo farmers.

The wealth of cultural remains in arid America provides a ready opportunity for pollen-stratigraphic study. Still unsolved is the cause of thirteenth century abandonment.

PHYSIOGRAPHIC DIVISIONS AND PHOTOGEOLOGIC MAP OF THE MOON

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The U. S. Geological Survey has made a stereoscopic study of the moon as part of a joint project in which the Army Map Service is preparing a topographic map of the moon. The study has been printed on a subdued photomosaic base at a scale of approximately 1:3,800,000 pending completion of the topographic map. On one map the lunar surface has been divided into physiographic regions to which 81 terms have been applied; principal features are also shown and named. For the photogeologic study a second map has been prepared dividing the rocks on the moon's surface into a sequence of three principal stratigraphic types; the map also shows distinguishable craters, domes, volcanic crater chains, faults and fractures, anticlines, monoclines, and other features of possible geologic significance. A third map depicts principal lunar rays, some of which extend more than 1000

miles from the crater of origin. An accompanying tabular text locates and characterizes each physiographic region, describes the materials composing the surface and selected features within the area, and evaluates landing and movement conditions and construction problems.

EVOLUTION, FUNCTION, AND DECAY OF FIRE ISLAND, NEW YORK

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Fire Island is a good example of man's interference with the processes of nature at the ultimate expense of man. The island barrier beach off Long Island consists of parallel sand dunes which separate the ocean from Great South Bay. The sand dunes evolved in succession out of sand bars which, once above tide levels, were compacted and further raised by the action of wind. Vegetation assisted the stabilization of dunes. The island protects Great South Bay, with its valuable fisheries, from the waves, sand, and salt of the ocean. Were the island not there, high ocean waves would flood low-lying portions of southern Long Island with its even more valuable agricultural and real-estate development.

Until the end of the nineteenth century, man did not make much use of Fire Island. Since then the use of beaches and the development of summer homes, and particularly the driving of cars across the dunes, have caused much dune erosion either directly, or indirectly through removal of the vegetation cover. The severity of erosion is to some degree a function of the real-estate development patterns characteristic of the island. Coupled with the greater frequency of hurricanes in the area and a possible rise in the level of the ocean, the erosion is a serious threat to the fisheries and developments on Long Island. For this reason the government is now spending about $40 million to raise and stabilize the dunes. The permanent success of this project will, however, depend upon the introduction of more serious restrictions on the activities of man (access, building, driving) on Fire Island.

GLACIER FLUCTUATIONS ON THE EASTERN SIDE OF THE SOUTH PATAGONIAN ANDES

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During 1958–1959, tree-ring studies were made on the eastern side of the Andes in the vicinity of the fiftieth parallel in order to date glacier fluctuations. The work was more difficult than expected since the *Nothofagus* forest is slow to recolonize ground bared by receding ice or water, and in places will not regenerate at all once destroyed; the limiting factor is the wind. Furthermore, the trees are very liable to suffer from internal rot.

Evidence was found for a wide variety of recent behavior. One glacier is advancing into mature forest, several reached a maximum in the late nineteenth century, and at least one, the largest in the area, in the late eighteenth century. The period of most rapid recession was usually in the decades immediately after the maximum. Since about 1910 most glaciers have changed little.

A short distance beyond most of the glaciers, there are one or sometimes two ancient moraines, usually much more massive than those formed in the eighteenth or nineteenth centuries. These moraines support mature forest with trees at least 500 years old.

CO-OPERATION THROUGH THE NEW YORK METROPOLITAN REGIONAL COUNCIL

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There must be intergovernmental co-operation throughout the New York-Connecticut-New Jersey metropolitan region, or else there is trouble ahead. There are hundreds of local governments in the region, and they have serious problems, such as inequities of tax burdens and public services, which are being intensified daily. These problems will grow worse unless we face the fact that our small

governments cannot struggle along in isolation. The Metropolitan Regional Council, formed 4 years ago, has already demonstrated that it can be the agency through which the region's local governments can work together on such regional problems as transportation, acquisition and preservation of park lands and open space, water supply, and air and water pollution.

Composed of the principal elected officials of 36 counties and cities, the Council is still only a voluntary agency. To have greater effectiveness, it should have formal status through official recognition by the legislatures of New York, New Jersey, and Connecticut; it also should establish a permanent, full-time secretariat to engage in constant study of the regional problems of the metropolitan area and submit frequent reports and recommendations to the full Council. A bill is soon to be introduced into the three legislatures providing for formal establishment of the Council. If the bill is enacted, the Council can proceed toward co-operative metropolitan government, without intrusion upon the rights, powers, and authority of the local governments or the State legislatures. The Council's role will not be that of a "super-government," but rather one of co-operation, advice, and assistance to the local, State, and Federal governments in dealing with the problems of the metropolitan area.

GEOGRAPHY AND ECONOMIC PLANNING AS ILLUSTRATED BY THE SOVIET ELECTRIC-POWER INDUSTRY

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The recent debate in the Soviet Union between advocates of thermal electric-power stations and hydroelectric advocates is indicative of a more basic division among Soviet geographers and economic planners. This division, roughly paralleling the determinism-possibilism split in American geography, separates those geographers who would study the physical aspects of Soviet geography as guides to what can be done in a given region from those who see nature as transformable through human action planned and co-ordinated by the State and Party. Although the electric-power debate ended in a compromise, with the decision to complete those hydroelectric facilities whose sites and multipurpose features were relatively most advantageous, the apparent divergence in viewpoint is so fundamental —and so characteristic of Soviet economic-geographic thought—that we can expect further and continuing manifestations of this division.

URBAN RENEWAL AND METROPOLITAN AFFAIRS

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The need for urban renewal action in our cities comes from two sources: (1) the continuous process of aging and deterioration of the physical plant, and (2) the backlog of blight that accumulated over the years before full-scale renewal was possible. Each city needs a crash program to eliminate this backlog, while establishing the mechanism to deal with deterioration and blight through continuing, normal operations of the local government.

A project-by-project approach can bring limited success, as long as there are "opportunity areas" where rock-bottom slums need to be cleared, and there are obvious new uses for the land. In order to deal with the entire backlog of blight, however, a city must take an inventory of its total need for renewal activity and of the resources available to meet that need.

This inventory involves questions—both economic and social—that can be answered only in terms of the entire metropolitan area. The same is true of other elements in the community-development process, such as mass transportation and water and sewer facilities. It is possible to plan on a metropolitan basis, but metropolitan planning does not feed into the decision-making process, which is fragmented among State and local political jurisdictions.

A possible solution would be the creation of *ad hoc* metropolitan development councils, composed

of local decision makers who have an understanding of metropolitan problems, the motivation to do something about them, and the power to act—each in his own field. Such a council should include both public officials and private citizens, with a permanent secretariat and the ability to draw on existing sources of data and planning information.

GLACIER RECONNAISSANCE, AMERICAN ROCKY MOUNTAINS, 1960

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There are more than 100 glaciers in the American Rocky Mountains; an accurate census has never been taken. Although these small glaciers are of scientific interest for many reasons—particularly as sensitive indicators of climatic change—less than a dozen of them have been observed systematically, and fewer have been studied intensively.

In 1960, a reconnaissance of these glaciers was undertaken with the aid of a grant from the Glacier Study Fund of the American Geographical Society. Localities and glaciers observed during the period July 21–August 16 were: *Colorado*—Blanca Peak, St. Mary's "Glacier," Arapaho Glacier, Rocky Mountain National Park (Tyndall and Andrews glaciers); *Wyoming*—Medicine Bow Mountains (Snowy Range), Grand Teton National Park (Teton Glacier), Absaroka Mountains; *Montana*—Beartooth Mountains (Grasshopper Glacier), Glacier National Park (Sperry Jackson, Blackfoot glaciers). The Big Horn Mountains in Wyoming and the Mission Range and Crazy Mountains in Montana were also briefly visited. All glaciers observed were in retreat. In some localities where the existence of glaciers had been in doubt because of popular confusions between glaciers and permanent snow fields, conclusive observations were made.

Record photographs were taken in all these places. Several hundred historic photographs, valuable for comparative purposes, were obtained after searching the archives of various institutions in the Rockies. All photographs and other unpublished glacier data have been added to the collections of IGY World Data Center A: Glaciology, to insure availability for future study.

GLACIAL CHRONOLOGY OF THE LAGUNA SAN RAFAEL AREA, SOUTHERN CHILE

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Radiocarbon dates on organic material collected in the Laguna San Rafael area, southern Chile, by the American Geographical Society Expedition of 1959 and analyzed by the Yale University Laboratory afford a chronology for comparison with other mid-latitude, west-coast, marine locations.

Previously reported geomorphic and stratigraphic data indicate that late Pleistocene transection glaciers gave way to piedmont and expanded foot glaciers which produced the Tempanos moraines during an interval of several centuries. Compressed *Nothofagus* wood 45 cm down in a 65-cm-thick peat layer beneath unweathered till 200 feet from the present edge of San Rafael glacier is dated at 6850 ± 200 years B.P. (Y-737). It is considered that Tempanos glaciation predated deposition of this peat and that deglaciation occurred prior to 9000 B.P., as shown by Auer to have been the case for glaciers in Tierra del Fuego.

Basal peat in a kettle lake between Tempanos I and II moraines near Ofqui (Y-738-2) and basal peat in a 182.5-cm organic zone over laminated silt near the north end of Rio Tempanos (Y-741) are dated at about 3600 years B.P. Available data do not indicate why bog accumulation did not begin earlier than indicated by these dates.

Unweathered till overlying peat 200 feet from the edge of San Rafael glacier presumably represents the historically documented advance which began a few centuries ago (Y-733, 734, 735).

COMPLEX SNOWFALL DISTRIBUTION OF NEW YORK STATE

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The main features of the distribution of mean seasonal snowfall in New York State are illustrated in an isorithm map. Only on an overlay placed over a contour map could a rational pattern of snowfall be recognized. The isorithms of snowfall were fitted to the snowfall data, and then drawn along terrain features with further reference to exposure to snow-bearing winds. Snowfall at higher elevations was estimated by extrapolation of rates of mean seasonal snowfall increase with elevation, and of the relationship between mean seasonal snowfall and the average depth of the snowcover on March 1.

The map reveals a complex pattern; mean seasonal snowfall ranges from a minimum of near 20 inches to a maximum of more than 200 inches. The two broad areas of excessive accumulation, as delimited by the 100-inch mean seasonal snowfall isorithm, are related to the pattern of snow squalls which frequently sweep the lee shores of Lake Ontario and Lake Erie. Mean seasonal snowfall in the Eastern Lake Ontario Snowbelt exceeds 200 inches on the summit of the Tug Hill Plateau at elevations below 2000 feet. Snowfall records indicate that this amount is not exceeded elsewhere in the United States east of the Rocky Mountains. Minimum snowfall is experienced along the southern shore of Long Island. However, deep "snow shadows" are in close juxtaposition with maximum accumulation areas in northern and central New York, where average snowfall in many of the valleys ranges between only 35 and 60 inches.

NATURAL CHROMATOGRAPHY AND THE GEOCHEMISTRY OF PETROLEUM ACCUMULATION

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Most sedimentary rocks contain colloidal-sized mineral particles. Through the pores of these rocks, *in situ*, fluids percolate. The sedimentary rock strata comprise, in effect, a very tall chromatographic column.

Small quantities of a large variety of organic compounds are incorporated usually in the loose, marine sediments before burial. Petroleum, however, which is the only major organic and fluid substance in consolidated sedimentary rocks, contains mainly hydrocarbons. Although there is evidence that a sizable portion of the organic compounds is immobilized early in diagenesis by the formation of particulate matter, a sufficient portion remains subject to flow. Experiments indicate that hydrocarbon compounds may travel with the least restraint during intrastratal fluid flow to the rocks which possess suitable capillary systems for accumulation. Other types of organic compounds may more easily be removed from the flowing phase and retained by colloidal rock constituents.

Petroleum, however, is itself a colloidal system. Some petroleums, such as the Athabasca bitumen in Alberta, Canada, contain large quantities of colloidal, asphaltene particles. Some of these particles are too large to have flowed through the smaller pore openings. Experiments show that oxidation and some other chemical reactions, taking effect after accumulation, may be responsible for the development of at least a part of the colloidal constituents.

The chromatographic mechanism appears to be useful in explaining the selective accumulation of petroleum hydrocarbons, even though the exact origin of these hydrocarbons is still being debated.

ACTIVE SUBSIDENCE IN THE NEW YORK AREA

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The tide-gauge record at New York city shows an apparent rise of sea level of 165 mm between 1900 and 1950. Analyses of world-wide tide records, selected to eliminate the tectonically more active regions and obviously unreliable stations, show a secular rise during that period of about 60 mm,

which is interpreted as eustatic. The residual anomaly of 105 mm, or approximately 2 mm per year, is attributed to contemporary subsidence. All eastern North American gauges show similar anomalies. The Atlantic Coastal Plain geosyncline, south of New York, readily explains this phenomenon; the subsidence north of this hinge may call for post-glacial crustal adjustment.

Marine sediments of Sangamon interglacial age (Pamlico/Cape May) occur from New Jersey south to Florida, at up to 25 feet above sea level. Northeast of New York, however, Sangamon equivalents (Gardiners clay, etc.) are rarely found undisturbed higher than 50 feet below sea level and drop to −100 feet in southern Long Island. Paleoecologically these formations, according to Richards, are all warm interglacials. If the age is approximately 100,000 years and the minimum tilt from New Jersey to Long Island is 25 m, then the maximum subsidence should be only 0.25 mm per year near New York city. It seems more likely that the secular subsidence is a purely post-glacial phenomenon, not older than about 15,000 years. The drowning of Long Island Sound and depressions to the northeast support this suggestion.

This subsidence is just the opposite in sign to a simple post-glacial isostatic rebound. It seems to be the peripheral bulge of Daly (and others) and may indeed be part of a highly viscous crustal ripple that migrated out from the retreating ice front.

CONSERVATION IN THE TRI-STATE NEW YORK METROPOLITAN REGION

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Although conservation is not often associated with the built-up portions of our nation, the Park, Recreation, and Open Space Project of Regional Plan Association has recognized this vital aspect in its open space plan for the Tri-State area which involves 22 counties in New York, New Jersey, and Connecticut. The region extends approximately 50 miles from the center of Manhattan and has an area of 7000 square miles. In 300 years about 25 per cent or 2000 square miles has been developed. If present trends continue, in the next 25 years it is estimated that the remainder, which is developable, may be so utilized. In addition, 8,000,000 people will be added to the present population of 16,000,000 by 1985. What portion of the land must be set aside for various conservation purposes and why? This is considered under four major points: to combat water shortages, floods, and air pollution; to protect the commercial fishing resources; for study and enlightenment; and for recreation and pleasure. To determine those areas with unique natural qualities in need of preservation the Project sponsored a pilot study in co-operation with the National Audubon Society. In the survey of the 22 counties more than 200 areas comprising more than 140,000 acres and representing more than 15 different types of habitat were recommended for immediate preservation. To acquire this acreage will mean public awareness, at all levels, of the importance these natural habitats serve in the ecological balance of any region. Immediate action is needed on the part of State, county, and municipal governments as well as private conservation agencies, for all have a role, and none can afford to wait.

TEKTITES AND THE CYRILLID SHOWER

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The name *cyrillids* is proposed for the great meteor procession of St. Cyril's day, February 9, 1913, following the precedent by which the perseids are sometimes called after St. Lawrence's day. The cyrillids are considered by most students to have been in orbit around the earth. They entered the atmosphere at exceptionally low speeds along a trajectory nearly parallel to the horizon. Öpik's theory of meteor ablation applied to this case indicates that the droplets should have had diameters of the order of a centimeter instead of the submillimeter droplets associated with some iron meteorite falls. Hanus and Hardcastle have proposed that this is the manner of formation of the tektites, on the basis of their shapes.

The detailed theory predicts a temperature of 2100°, in agreement with the lack of water. It pre-

dicts a time of heating of the order of 10 minutes, in agreement with the evidence from magnetic measurements, which give a lower limit, and from the presence of streaks of amorphous SiO_2 (lechatelierite), which set an upper limit. The time is confirmed by the apparent conversion of the oxide to FeO. The theory is consistent with the theories of G. Baker (1959) on the location of australite flanges and their apparent mode of formation from thin liquid layers.

THEORY OF THE DISTRIBUTION OF TEKTITES

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An attempt is made to correlate the observed tektite distribution with the hypothesis of a lunar origin. Such an origin would provide evidence on the chemical composition of the moon. The assumption is that the perigee of a large body in an eccentric satellitic orbit is pushed into the earth's atmosphere by lunar-solar perturbations. Droplets are sprayed off as the body goes through the atmosphere. Depending on their size or drag coefficients, these fall quickly or go around again. Those that go around again have different periods caused by their times of leaving the main body and their size, so they arrive at the next perigee pass at different times. The earth rotates underneath the orbit between their different times of arrival and thus causes a longitude spread in the fall. They fall in different latitudes according to their energy and drag coefficient, and an area distribution is produced. Their actual trajectories with impact points are being investigated by numerical computations using an orbit routine with an oblate earth approximation and an atmosphere in an attempt to produce an areal distribution similar to the australites.

CONTINENTAL SHELF: PHYSICAL *VS.* LEGAL DEFINITION

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Although difficult to define in precise language, the continental shelf in a physical sense is well known. It consists of a shallow submarine platform extending seaward from the continental land masses. It may be extremely narrow—virtually nonexistent—or it may measure as much as 800 miles in width. The maximum depth, however, varies but little, generally approximating 100 fathoms or 200 meters. At its outer edge this gently sloping platform tends to break suddenly and plunge to great depths.

With recent interest in Law of the Sea matters the continental shelf gained prominence in international law. The legal profession needed to identify the zone of shallow water adjacent to any given State. Moreover, sovereignty of the water itself needed to be distinguished from that of the submarine platform beneath it. In the 1958 Geneva Law of the Sea Convention a legal definition of the term "continental shelf" was promulgated by the wording, "the seabed and subsoil of the submarine areas adjacent to the coast but outside the area of the territorial sea, to a depth of 200 meters or, beyond that limit, to where the depth of the superjacent waters admits of the exploitation of the natural resources of the said areas."

Thus, the territorial waters of a State may extend "x" miles from the shore line, but the continental shelf goes beyond to give to that State all offshore natural resources dissociated from the water itself.

URBAN RENEWAL IN THE CITY OF NEW YORK

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New York, along with the other major cities of the nation, welcomed the chance offered by the Housing Act of 1949 to eradicate the century-old accumulation of structural obsolescence. The program of slum clearance and redevelopment undertaken here (the largest in the nation) evolved from

the "bulldozer" approach to the problem of slum and blight elimination. Notwithstanding the dramatic achievements of the New York Slum Clearance Program, the shortcomings of the "project" approach became more evident with every new project announced by the Mayor's Committee on Slum Clearance.

The principal difficulties to be resolved if the program was not to grind to a standstill included that of relocating thousands of families in the face of a dwindling supply of low-income housing, and the slowness of the rate of slum eliminating as compared with the almost frightening rate of slum formation. Recognition on the national level of the shortcomings in this respect of the Housing Act of 1949 was responsible for the enactment of the Housing Act of 1954. In New York, the West Side Urban Renewal Project was the first project to employ the technique of combining clearance of dilapidated structures with rehabilitation and conservation measures intended to prolong the economic life of the remainder.

Experience with this project and accumulated experience elsewhere throughout the country led to the enactment, in the Housing Act of 1959, of the Community Renewal Program approach. Now, for the first time, along with other aging cities where obsolescence has become an acute problem, New York can expect wise and humane scheduling of slum-clearance operations, reclamation of salvageable neighborhoods, blight prevention, and continuity of renewal activities within the framework of a broadly conceived long-range Master Plan.

HEAT AND WATER BALANCE RESEARCH AND THE ROLE OF SOVIET GEOGRAPHY THEREIN

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Although man has appreciated the life-giving qualities of heat and water for centuries past, it is only recently that he has begun to understand the special importance they have in the formation of his environment. The effectiveness of his use of the environment has been lessened by the lack of insight into the complex character of the causal factors and certain underlying thermal and hydrologic conditions and of the impact of these conditions on their surroundings. Attempting to master these problems, science has made significant progress in analyzing heat and water equilibria in the biosphere and in predicting the probable results of an upset in these equilibria.

The Soviet Union whose territory includes polar ice fields and subtropical lowlands, extensive marshes, and deserts, and which must wage a constant campaign to produce more food products for its growing population, is particularly well suited to stimulate interest in studies of heat and water balances. It is, therefore, not surprising that Russian scientists have made a sizable contribution to knowledge in this area and that their current research promises to be of even greater significance.

This paper will attempt to sketch out the present limits of Russian research on heat and water balance and to show the role that Soviet geography plays in this research.

CHILEAN EARTHQUAKES OF 1960

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Southern Chile was severely shaken by an earthquake swarm that began on 21 May 1960 and culminated with a magnitude 8¼ shock on 22 May.

The causative fault was beneath the sea, and the slippage probably extended over 1200 km. A maremoto was produced. Volcán Puyehue began erupting ash at 1400 local time on 24 May. The eruption lasted several weeks, terminating in short flows of viscous lava. Changes of land level were noted. Isla Guafo, Isla Mocha, and the western part of the Arauco Penninsula rose 1 to 2 m. The coast line from Pto. Saavedra to the south end of Isla Chiloé subsided a like amount.

Deposits of glacial (Pleistocene) clay and silts turned liquid under the vibrations and flowed, producing damages in all the major towns between Concepción and Pto. Aysén.

Damages to homes and industry exceed $400,000,000; 1,400,000 people need new homes, and 2000 people were killed or lost. Damage to agriculture and livestock raising is large owing to loss of arable land by inundation.

FOREIGN TRADE POLICIES AFFECTING MINERAL FUELS IN THE UNITED STATES AND WESTERN EUROPE

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Since the end of World War II the United States and Western Europe have both come to rely increasingly on imports of mineral fuels—particularly crude oil and its products. Importation into the United States reflects not an absolute deficiency in domestic resources, but rather the fact that oil can be produced more cheaply in other parts of the world. Importation into Western Europe reflects the change now under way in the pattern of fuel consumption, away from coal and toward oil and gas. Because of the shortage of indigenous oil and gas resources in Western Euorpe this change in consumption pattern, which is deemed desirable, can be realized only if imports are greatly increased.

The importation of so vital a commodity as oil gives rise to serious problems of policy affecting the economic, political, and military security of the importing countries. Yet, the United States and Western Europe pursue completely independent and unco-ordinated energy trade policies. At the present time United States policy is openly protectionist in that there are quota restrictions on the importation of oil and oil products. Western Europe, on the other hand, is tending toward free trade in energy materials, although protectionist measures, presumably of a short-term nature, are being employed in some of the countries. What are the implications for the United States and Western Europe of the simultaneous pursuit of opposite policies? Is greater policy co-ordination desirable? What would be the elements of a co-ordinated energy policy for the United States and Western Europe? Answers to such questions will assume a fresh urgency with the transformation of the Organisation for European Economic Cooperation (OEEC) into a broader organization which for the first time includes non-European members, among them the United States.

GEOLOGICAL EXPLORATION OF THE MOON

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A successful lunar exploration, capable of ultimately eliciting the origin and history of the moon, must be based on a geological survey. Satellites can be used for aerial mapping. Surface exploration packages (involving roving vehicles, deep drilling, and/or return of samples to earth) can provide highly localized information on the type, composition, and texture of surface materials, as well as data on climate and seismic activity. Ultimately, manned exploration can provide more detailed and specialized data.

As in terrestrial explorations, the chief difficulty will lie in the extrapolation of data from a few localized explorations into a reliable over-all picture of the geological provinces and forces of the moon. Therefore a thorough mapping program, with successively more detailed interpretations (in terms of the surface-exploration data), will be of primary importance. The value of the data can be greatly enhanced by optimum utilization of astronomical, satellite, and entry-probe data in the choice of soft-landing sites and appropriate experimental instrumentation, and by controlled, rather than random, sampling of surface materials.

ORIGIN OF THE RIES BASIN, BAVARIA, GERMANY

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The Ries basin is a shallow nearly circular depression about 17 miles in diameter that lies between the Schwäbian and Franken plateaus of southern Germany. Great masses of breccia and a system of

thrust sheets associated with the Ries have been studied by German geologists for about a century. E. Werner and Otto Stutzer suggested the Ries was an impact crater, but the consensus of the principal investigators has been that the basin was formed by some sort of volcanic explosion.

The only direct evidence of magmatic activity at the Ries is the presence of glass in scattered patches of a breccia called *suevit*. Some of the glass has long been recognized as sintered fragments of old crystalline rocks. We have found that coesite, a high-pressure polymorph of SiO_2, and lechatelierite, SiO_2 glass, are constituents of the sintered rocks in the *suevit*. The occurrence of the same phases in sintered rock fragments of Meteor Crater, Arizona, suggests that the glassy components of *suevit* are impactite rather than volcanic in origin.

STRATIGRAPHIC BASIS FOR A LUNAR TIME SCALE

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The geological law of superposition is as valid for the moon as it is for the earth, although at the present stage of lunar exploration the conditions of application of the principle of superposition are somewhat different. Gross temporal relations of many visible features of the lunar surface can be determined from their surface pattern. In most cases the observable features can be inferred to be underlain by strata or lenticular to irregular bodies of rock or rock debris. The lunar surface is built up primarily of an imbricate and complexly overlapping set of layers of ejecta from craters, material underlying the crater floors, and material that occupies the smoother floors of the maria.

Five major stratigraphic subdivisions have been recognized. In descending order these subdivisions include the following: (1) rays and the rim ejecta of ray craters, (2) rim ejecta of certain craters that resemble ray craters but are unaccompanied by rays, (3) the material of the maria floors, (4) a great sheet of ejecta associated with Mare Imbrium and the rim ejecta of certain craters superimposed on this sheet, and (5) rim ejecta and floor material of craters on which the Imbrium ejecta sheet is superimposed. Photogeologic mapping indicates that each of these five subdivisions can probably be correlated over most of the visible hemisphere of the moon. A lunar time scale corresponding to these five stratigraphic subdivisions is proposed.

METHODOLOGICAL CONTROVERSY IN SOVIET GEOGRAPHY

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Since 1930, a bitter methodological debate has raged intermittently in Soviet geography over the nature of geography in general and, more specifically, over the classical forms of dualism in geography. The economic geographers at Moscow University, who form the regional school in Soviet geography, together with Lev Berg and many other members of the landschaft direction in physical geography, have been the leading advocates of a unified geography and, concomitantly, an integrative regional approach. These geographers have frequently clashed with geographers and economists associated with the Academy of Sciences, who have maintained that economic and physical geography are independent sciences. According to this view, attempts to group these disciplines into a unified science of geography are attributable to Hettnerian influences and lead to "anti-Marxist geographical determinism." In reply, the regionalists assert that their opponents underestimate the importance of regionalists studies in favor of a systematic approach and are guilty of "anti-Marxist indeterminism." Kantian philosophy has also been introduced into the debate, although in a negative sense. The regionalists have been accused of espousing the Kantian classification of sciences. In turn, they have retorted that efforts to erect an impenetrable barrier between cultural and physical geography reflect "Kantian subjectivism."

The attacks on a unified geography began in 1930 as part of a drive to "cleanse Soviet science of bourgeoise influences" and, also, as a reaction against Western location theory, which was used by opponents of the Ural-Kuznetsk Kombinat. After an uneasy 20-year truce, these attacks were renewed in the early 1950's. To a considerable degree, methodological controversy over the nature of

geography was resolved at the Second Congress of the All-Union Geographical Society in 1955, when economic and physical geography were declared to be distinctive sciences within a closely integrated complex of geographical sciences.

NATURAL LEVEES AS FOREST SITES: A CALIFORNIA EXAMPLE

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The vegetation of the Sacramento Valley (used here in the local sense, restricted to the alluvial lowlands bordering the Sacramento River below Red Bluff, extending about 150 miles north-south and averaging about 30 miles east-west) during late Indian occupancy consisted essentially of two plant associations. Most extensive was the grassland community, in some areas interspersed with scattered oaks; elsewhere, on the lower portions of the flood plain, was a marsh-grass community. Also present, but often overlooked by modern students, was a woodland belt on the natural levees bordering the Sacramento River and tributaries. This belt was in places several miles wide and formed the only continuous forest on the 5000 square miles of Valley floor.

A combination of several factors, mainly structural and climatic, promoted the development of extensive natural levees along the lower Sacramento River and tributaries. In turn, these permitted trees to flourish on the levees, safe from the inundations and excessively high water tables that prevented them from growing elsewhere on the flood plain. The uneven character and irregular extent of the levee forests are deduced from historical sources.

The aboriginal equilibrium in the Sacramento Valley was drastically upset by the invasion of white settlers. The levee forests were quickly attacked during the early years of American occupancy. A number of reasons explain this attack. The levee forests provided construction materials and fuel for a wide area of the treeless valley and for the busy river traffic. The forests were also cleared because the natural levees were first to attract settlement—by their fertile, easily managed soils, their comparative freedom from flooding, and easy access to transportation. Thus the levee forests were nearly eliminated during the first 20 years of American occupancy. Today almost no traces remain, and the Sacramento Valley has a striking, even dismaying, paucity of trees.

LUNAR TERRAIN ANALYSIS

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Terrain may be considered to be the sum of the various physical attributes that describe the landscapes of a region. Terrain can thus be analyzed and described in terms of numerous component factors. Terrain factors can be defined and stratified, in a qualitative or quantitative manner, by utilizing a wide variety of measuring and descriptive techniques. Measurement and description of lunar terrain factors will be long dependent on the interpretation of images or returns produced by photographic and electromagnetic-electronic sensing devices. Based on the interpretation of sensor returns, "equivalents" of lunar terrain types or terrain factors—such as surface roughness, consistency, and rock type—must be located or artificially produced. Estimates concerning the effect of these types or factors on specific lunar operations or equipment must be predicated on Earth-based "field" testing of lunar equivalents. These estimates will aid in the selection of landing sites and provide design-criteria data for vehicle landing gear, stationary and roving telemetering units, and many other systems and equipments.

Ultimate goals of the above-mentioned studies include (1) the establishment of quantitative relationships among terrain factors, or pertinent groups of factors, and their effects on specific lunar-exploration activities, and (2) the delineation of areas of analogous effects. These monumental objectives can best be served by a comprehensive and intensive program aimed at the improvement of geologic methods, techniques, and equipments—with special emphasis on noncontact data collection and interpretation.

INCOME FRONTS AND MIGRATION IN THE UNITED STATES—A STUDY IN MACROGEOGRAPHY

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The recognition of two major income fronts in the United States makes possible a clearer understanding of the nature of a variety of social and economic problems. In this paper attention will be centered upon internal migration.

From the given present microgeographic distribution of income, a spatially continuous macrogeographic distribution, the incom potential field analogous to gravitational or electro-static potential fields, is created. This smooth surface serves as a means for providing smoothed income density and per capita income surfaces. To a first approximation the income density surface is continuous throughout, whereas the per capita income surface exhibits two major breaks or discontinuities. Analogies to certain meteorological concepts employed in air-mass analysis suggest naming these discontinuities income fronts.

Presumably resulting from a complex of events including the discovery of valuable minerals in the Far West as well as the Civil War, these income fronts have exhibited a decided long-run trend toward dissipation. Measures of this exhibited dissipation can be shown to be functionally related to the macroscopic migration patterns in the United States from the Civil War to the present. Certain guarded predictions concerning the future distribution of income and population in the United States are possible.

The relation of the above to other major economic and social phenomena will be demonstrated with emphasis upon the methods and concepts being developed in the research program in macrogeography at the American Geographical Society.

SECONDARY MINERALIZATION IN WIND CAVE, SOUTH DAKOTA

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Wind Cave is located in Wind Cave National Park, South Dakota, in the Mississippian Pahasapa limestone in the southeastern margin of the Black Hills. Much secondary mineralization has taken place in the cave, but it appears to have been deposited subaqueously. The subaerial calcite deposits common to most limestone caves are rare, although calcite is common. Other minerals identified include gypsum, aragonite, hydromagnesite, quartz, and hematite. Calcite is deposited as a layer of clear coarse-grained crystals that coats most of the cave walls. The "boxwork" of Wind Cave is composed of a pink core of calcite with up to 5 per cent other carbonates in solid solution sandwiched between two layers of clear calcite. Calcite also forms minor coatings and botryoidal forms. Gypsum occurs as thin crusts on walls, as long thin selenite needles, and as tufts of "cave cotton". Aragonite occurs as tufts of acicular crystals on walls. Hydromagnesite is found as white patches on ledges and appears to be one of the last minerals deposited. Hematite and quartz appear intergrown with calcite in geodes and boxwork cores.

The apparent sequence of events in the cave is:

(1) Formation of boxwork cores and a few geodes by fracture filling within the limestone.

(2) Solution of the limestone to form the cave leaving the less soluble boxwork standing out in relief.

(3) Deposition of a thin layer of silt on upward facing surfaces.

(4) Deposition of a complex layer of calcite subaqueously on most surfaces.

(5) A second and more intensive period of deposition and cementing of silt.

(6) Draining of the cave and deposition of the subaerial forms.

STRATIGRAPHIC PALYNOLOGY AS A TOOL FOR COMMERCIAL GEOLOGY

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Palynology is a valuable stratigraphic and paleoecological tool, and as such it has been extensively used by the petroleum industry. This paper is an attempt to summarize difficult problems that lie ahead in the application of the method and to sound a word of caution to those who are not aware of its limitations. Palynology will become increasingly important to industry as the inherent problems are resolved, but at present only broad interpretations should be drawn from palynological data because many fundamental aspects of the science are still unknown.

Among the problems confronting the palynologist are evolution and taxonomy of palynological fossils, and the paleogeographic and paleoecologic conditions that influence biostratigraphic analysis. Palynology is not a minor discipline, and one qualified to cope with its problems must have the widest possible background in biology and geology.

REAPPRAISAL OF APPALACHIAN GEOLOGY

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Long a laboratory for thousands of geology students, the Appalachian region has provided most fossil types and formational standards for the American Paleozoic. It has nourished major concepts of physiography, structural geology, orogenesis, and stratigraphy, and one might imagine its geology to be thoroughly understood. Yet it is still full of geologic enigmas. Too many familiar elements of its geologic history need revision, and the entire province should be restudied in the light of new information, new methods of study, and new angles of approach.

Knowledge of Appalachian stratigraphy is extremely uneven, ranging from good to vague at different localities and horizons; large areas are geologically unmapped even at reconnaissance levels; systemic boundaries are indefinite, and various thick formations need subdivision. The eastern extensions of most Appalachian rocks are complicated by deformation, and too little is known about this half of the basin.

Rhythms in Appalachian geology have been unsuccessfully sought: perhaps none exists; perhaps new directions of attack should be tried. The timing, distribution, and results of Appalachian orogenies should be re-examined as well as the character of its folds and faults.

On the positive side, modern radioactive dating is immensely improving historical interpretation while various subsurface studies plus innumerable new exposures are adding much new information. Vigorous efforts of new branches of geoscience have stimulated a new era in Appalachian geology.

Most significant is the appreciation that new concepts are in the wind—a realization of the inadequacy of older stereotyped views and a genuine intention to replace them with more accurate interpretations.

FUNCTIONAL SUBDIVISIONS OF THE PEORIA, ILLINOIS, URBAN AREA

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By combining census data for unit statistical areas with selected measurements made from contemporaneous aerial photographs, I have mapped land use, population distribution, building density, street pattern, and employment centers for the Peoria, Illinois, urban area. These patterns are being correlated with a detailed Origination and Destination traffic survey. Some of the procedures and findings of this work are reported elsewhere.

The purpose of this paper is to report on a functional synthesis of some of the intra-urban patterns revealed by the basic data. These patterns are interpreted in the light of other data in order to subdivide the urban area into kinds, or "levels," of sub-urban places. These, in turn, are divided into 21 lesser divisions called "Functional Areas." One of these is the "Peoria Core Commercial District

'Central' "—the Central Business District. Another is "Peoria Ancillary Industrial Community 'Bartonville';" and so on.

Each functional area, and level of functional area, is characterized in terms of the quantitative data for component statistical areas derived from the census and photographs. The sum of these provides a kind of statistical model, or photo-interpretation key, for urban areas similar to Peoria. The paper suggests how the model might be used to estimate similar data for other urban areas for which aerial photographs are available but the control data are not. Some uses of the resultant urban-area analyses are mentioned. These result from improved urban comparisons made possible by the system of measurements and the classification of data for unit statistical areas.

STATUS OF PALEONTOLOGY

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Emphasis in paleontology has changed in the last several decades, and paleontologists are now increasingly concerned with fossils as former living organisms rather than as "things in rocks". This change is reflected both in the more widespread interest in patterns and problems of evolution and in the de-emphasis of former divisions between pure and applied paleontology. Besides application of fossils to local problems of dating and correlation, more general studies are being made of intercontinental correlation, paleoclimatology, and paleogeography. Improved techniques are providing more and better fossils and are particularly significant for commercially important microfossils.

Many recently published studies are limited biologically rather than stratigraphically. Paradoxically, there has been an explosive interest in paleoecology, the relations of fossil organisms to each other and to their former environment. Paleoecology will be an active field for at least the next decade. Newly developing techniques in geochemistry and geophysics may eventually supplant paleontologic interpretation in this area, but it is unlikely that they will be more than supplementary for many years to come.

The growth rate of paleontology seems disappointingly slow relative to other fields of geology. In part this is a result of the random nature of discovery and study of fossils. Equally, it indicates inadequate biological training of most geologists. This unfortunate situation can be corrected only by changing university curricula so that fossils receive as much emphasis as that devoted to minerals. Limited support and personnel will continue to prevent geologists from reaping the full benefit of paleontological experience.

MEANING AND NEED OF NATURAL-RESOURCE PROGRAMMING

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Between 1930 and 1950 attitudes toward natural resources underwent a radical change from one of indifference in the face of limitless supplies to one of anxiety in the face of limitless needs. The reasons for this shift may be attributed to two factors: (1) the increase in world population, and (2) the rise in per-capita living standards. Taken together these factors have resulted in an exponential expansion in the demand for earth's raw-material resources, which may threaten to run ahead of the releases of new supplies by science and technology. Malthusian-type predictions became common.

Concern over such problems has resulted in the emergence of new concepts of resource use. One of these seeks to develop rationalized procedures for the use and production of natural resources. It is referred to as resource programming. The approach may deal with single raw materials or with resource complexes, or with the set of materials that constitutes the resource base. Resource programming as a way of arriving at allocating decisions will grow in importance in the future. Decision-making criteria based on profit maximization of the individual firm will be replaced by those based on social welfare considerations. Resource programming may be viewed generally as a rational approach to the use and development of raw materials or, technically, as a mathematical decision-making tool which reaches optimum solutions.

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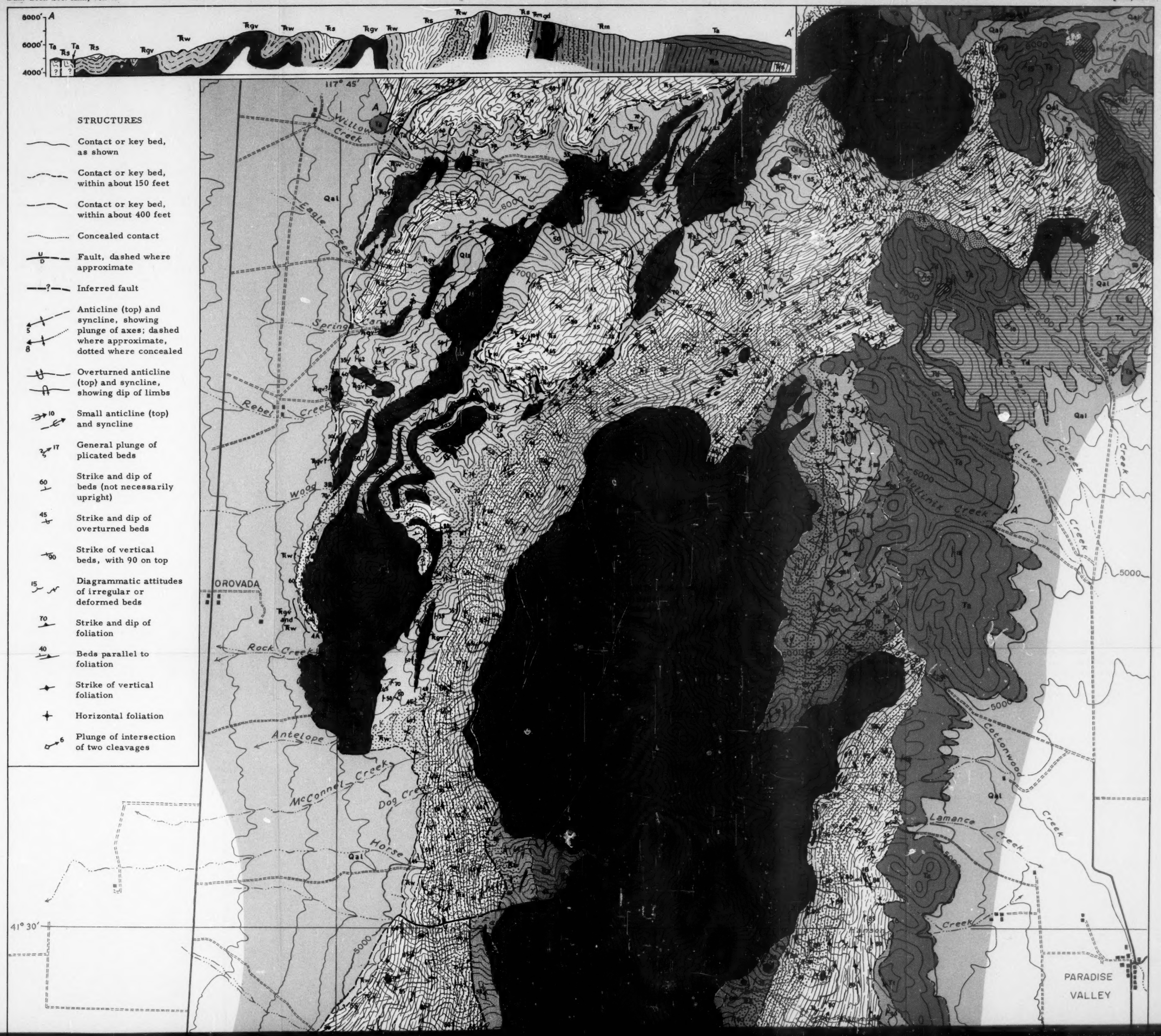
12. TERTIARY FLORA FROM THE RIO PICHILEUFU, ARGENTINA. E. W. Berry. 1938. 149 p., 56 pls., 11 figs. $2.10.
21. PALEONTOLOGY AND STRATIGRAPHY OF THE SILURIAN ROCKS OF THE PORT DANIEL BLACK CAPE REGION, GASPE. S. A. Northrop. 1939. 302 p., 28 pls., 1 fig. $3.00.
28. REVIEW OF THE PELYCOSAURIA. A. S. Romer and L. I. Price. 1949. 538 p., 46 pls., 71 figs. $4.20.
29. PHACOPID TRILOBITES OF NORTH AMERICA. D. M. Delo. 1940. 135 p., 13 pls., $1.20.
33. NUMERICAL STRUCTURE FACTOR TABLES. M. J. Buerger. Reprinted 1953. 119 p., 4 figs. (Cloth bound) $1.50.
37. OZARKIAN AND CANADIAN CEPHALOPODS, Part I, Nautilicones. E. O. Ulrich, Aug. F. Foerste, A. K. Miller and W. M. Furnish. 1942. 157 p., 57 pls., 23 figs. $2.40.
60. GLACIAL MAP OF NORTH AMERICA. By Committee on Glacial Map. R. F. Flint, *Chairman*. 9945. $2.00.
62. CRUST OF THE EARTH. Arie Poldervaart, *Editor*. 1955. 762 p. $6.50.
63. DE NATURA FOSSILIUM, by Georgius Agricola. Translated by M. C. Bandy and J. A. Bandy. 1955. 240 p. $3.00.
64. MARYSVALE, UTAH, URANIUM AREA. Paul F. Kerr *et al*. 1957. 212 p., 21 pls., 106 figs. $6.00.

(Continued on inside back cover)


8000'
6000'
4000'
A
A'
Ta
Ts
Tgv
Tw
Tm
Tmgd
STRUCTURES
Contact or key bed, as shown
Contact or key bed, within about 150 feet
Contact or key bed, within about 400 feet
Concealed contact
Fault, dashed where approximate
Inferred fault
Anticline (top) and syncline, showing plunge of axes; dashed where approximate, dotted where concealed
Overturned anticline (top) and syncline, showing dip of limbs
Small anticline (top) and syncline
General plunge of plicated beds
Strike and dip of beds (not necessarily upright)
Strike and dip of overturned beds
Strike of vertical beds, with 90 on top
Diagrammatic attitudes of irregular or deformed beds
Strike and dip of foliation
Beds parallel to foliation
Strike of vertical foliation
Horizontal foliation
Plunge of intersection of two cleavages
117° 45'
41° 30'
Willow Creek
Eagle Creek
Spring
Rebel
Wood
Rock Creek
Antelope
McConnel Creek
Dog Creek
Horse
Qal
Qts
OROVADA
Silver Creek
Quinn River
Cottonwood Creek
Lamance Creek
PARADISE VALLEY
5000
6000
7000

Strike of vertical foliation

Horizontal foliation

Plunge of intersection of two cleavages

41° 30'

Antelope

McConnel Creek

Dog Creek

Horse

Qal

5000

Andorno Creek

Cottonwood Creek

Lamance Creek

Creek

PARADISE VALLEY

Gingas Creek

Qat

Tt

Ta

Tw

Ro

Rm

Rmv

Rmt

Rmf

Rmm

Rmc

Rmg

Rmd

Rmh

Rmp

Rmq

Rmr

Rmw

Rmx

Rmy

Rmz

Rmk

Rmn

Rmo

Rmu

NEVADA HIGHWAY 8A

AMOS

CANE SPRINGS

Chimney Creek

Porcupine Creek

Bronco Creek

Canyon Creek

TRAM BUTTE

HOUGH MINE

×7218

×4464

NEVADA HIGHWAY 8B

PARADISE HILL STATION (FLYNN STATION)

U.S. HIGHWAY 95

ABANDONED HIGHWAY 95

41° 15'

18°

TRUE NORTH

MAGNETIC NORTH

0 5,000 10,000 15,000 Feet

0 1 2 3 Miles

Contour interval 200 feet

ROCKS

QUATERNARY

- Qls — Landslide
- Qal — Alluvium and minor till

MIOCENE OR PLIOCENE

- db — Olivine diabase dikes
- Ta — Intrusive andesite
- Tda — Intrusive dacite and rhyolite
- Td — Mainly dacite and rhyolite flows
- Ta — Mainly andesite flows
- Tt — Mainly tuff
- Contact zone of porphyroblastic fine-grained rocks
- Contact zone of coarser-grained hornfels and schist

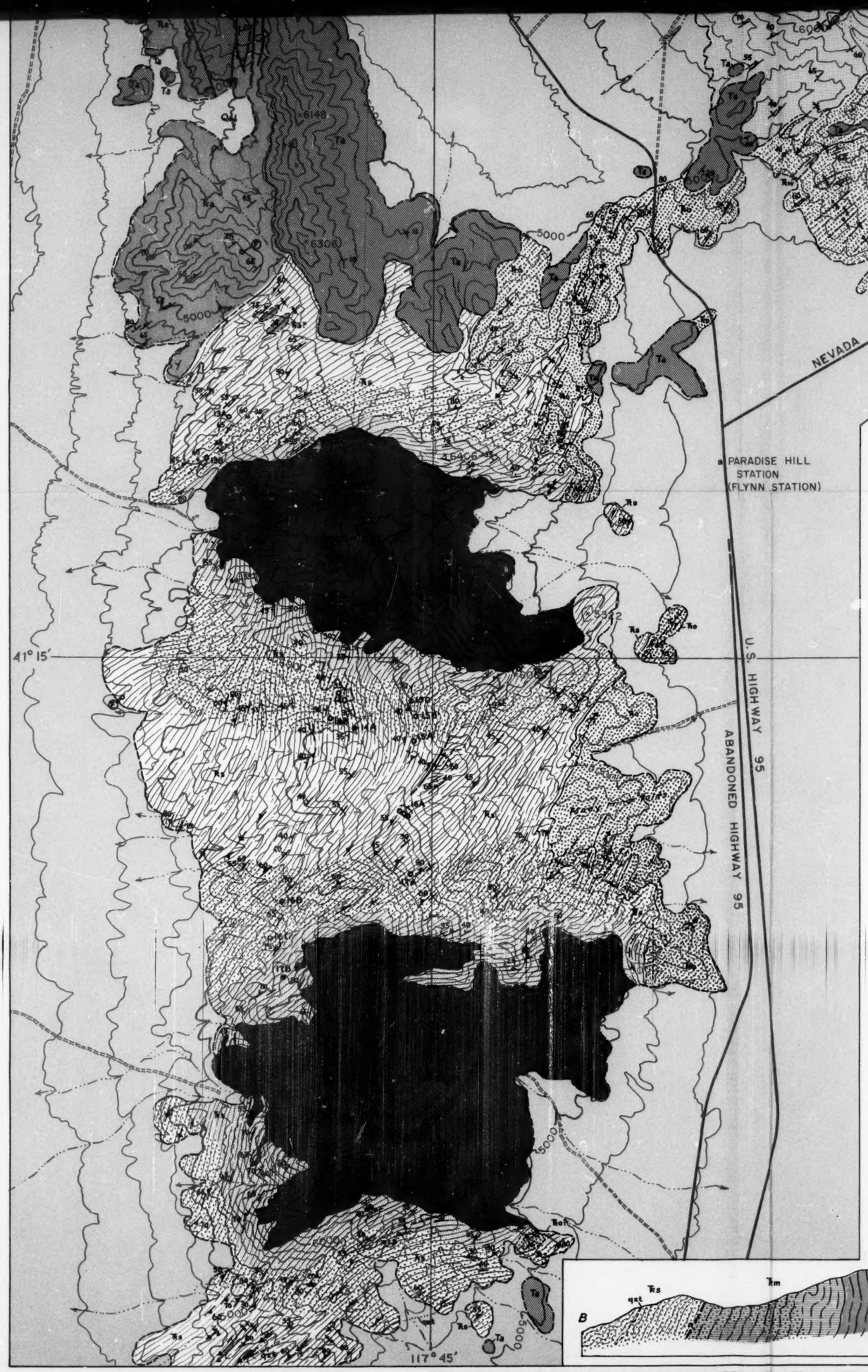
LATE CRETACEOUS TO EARLY TERTIARY

- Granitic intrusive rocks (color is for main rock in each stock; gd = granodiorite, ad = adamellite, td = trondhjemite, ? = questionable assignment)
- mi — Mafic and ultramafic intrusive rocks

LATE TRIASSIC

- ? —
- Tm — Mullinix formation
- Ta — Andorno formation
- Ts — Singas formation
- To — O'Neill formation
- Tw — Winnemucca formation
- Grass Valley formation

- Fossil locality
- 13 — Locality of analyzed rock sample



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0 1 2 3 Miles

Contour interval 200 feet

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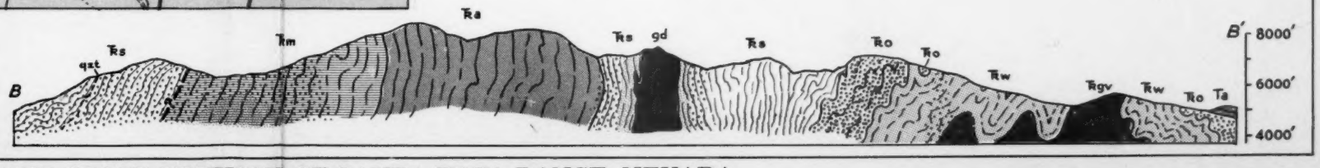
Note: houses and most unpaved roads are diagrammatic only.

Topography and culture mainly from preliminary topographic maps of the U. S. Geological Survey and Army Map Service.

Geology by R. Compton (1952-1958) and field classes of Stanford University, including P. Abell, F. Atchley (instructor), M. Barnard, N. Bostick (instructor), S. Breiner, F. Capra, Jr., G. Clum, W. Dickinson (instructor), R. Dobbs (instructor), D. Elliott, Jr., H. Evans, J. Fairborn, W. Findlay, Jr., G. Fowles, P. Friedman, R. Gant, E. Gardner, Jr., R. Garrison, D. Gielow, J. Groom, C. Gutierrez, S. Havenstrite, T. Herman, A. Hilton, M. Jager, Y. Javeri, E. Jenkins, J. Laak, C. Lao, D. Lee (instructor), J. Leet, C. Lindvall, R. Long, A. Loskamp, H. Loskamp, R. MacColl, J. Mack, J. McHenry, R. Merrick, S. Mitchell, E. Montgomery, S. Morris, G. Mowat, J. Ojeda, F. Ortiz, F. Park, P. Persons, K. Pierce, R. Pinezich, D. Pollard, P. Randau, J. Rietman, W. Scheidecker, J. Sides, G. Sorensen, D. Speyer, Cecil Taylor, Charles Taylor, S. Taylor, M. Thacker, H. Townsend, III, R. Trimingham, O. van West, P. Weber, H. Whitten, Jr., W. Wise (instructor), and L. Wood.



GEOLOGIC MAP AND CROSS SECTIONS OF SANTA ROSA RANGE, NEVADA

GEOLOGIC MAP AND SECTIONS OF THE WABUSH LAKE AREA

SOUTHWESTERN LABRADOR AND EASTERN QUEBEC

COMPILED AND EDITED BY GORDON GASTIL AND DAVID M. KNOWLES

The area is one of limited rock exposure and lithologic contacts are largely interpretive. Information has been obtained from geologic maps contributed by Canadian Javelin Ltd., the Newfoundland and Labrador Corporation, Cartier Mining Company, and Jones and Laughlin Steel Corporation, and from ground and aerial magnetic survey and drill core data contributed by Canadian Javelin Ltd. Use has also been made of published maps by the Geological Survey of Canada and the Quebec Department of Mines (see text for acknowledgements).

GEOLOGIC SECTIONS

VERTICAL AND HORIZONTAL SCALE IN MILES

0 5 10

EXPLANATION

MAP SECTION

Rock overlying iron formation
- k graphitic muscovite phyllite, schist, and gneiss, coarse-grained garnet, muscovite schist, and kyanite schist
- a amphibolite
- cs calc-schist (some rock of meta-igneous origin may be found)

unconformity

Wabush Lake iron formation
- if undifferentiated
- h hematite facies
- m magnetite, martite facies
- s silicate facies
- c carbonate facies
- q iron-poor meta chert

Wapussakatoo quartzite
- w quartzite
- z muscovite unit

Duley marble
- d meta carbonate rock
- sc schist, gneiss

unconformity

Rocks underlying Wapussakatoo quartzite and Duley marble
- fb fine-grained biotitegneiss
- b coarse-grained biotitegneiss
- n granitic gneiss

Undifferentiated rocks
- u Wapussakatoo quartzite, Wabush Lake iron formation, and overlying rock units
- sc undivided schist
- ? bedrock unknown

Mafic igneous rocks
- g gabbro, diabase
- lg leucogabbro
- hg hornblende-garnet gneiss
- ct chlorite-talc schist

≥1000 my in age

Strike and dip of bedding

Strike and dip of foliation in schist and gneisses, and of lamination in mafic igneous rocks

Structural discontinuities of unknown nature, interpreted in section as low-angle faults

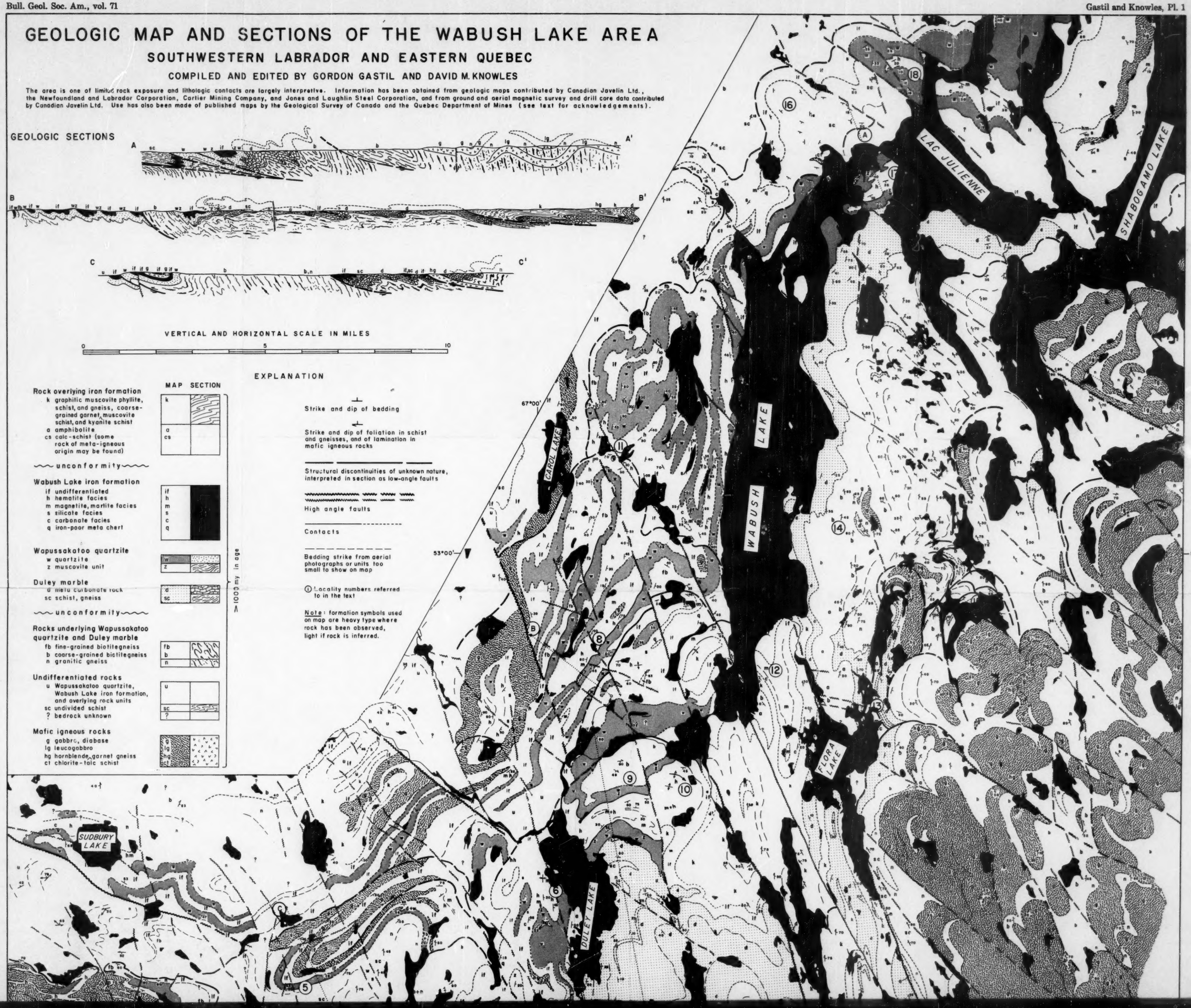
High angle faults

Contacts

Bedding strike from aerial photographs or units too small to show on map

① Locality numbers referred to in the text

Note: formation symbols used on map are heavy type where rock has been observed, light if rock is inferred.



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Note: formation symbols used on map are heavy type where rock has been observed, light if rock is inferred.

67°00'

53°00'

52°45'

CAROL LAKE

WABUSH LAKE

FLORA LAKE

DULEY LAKE

SUDBURY LAKE

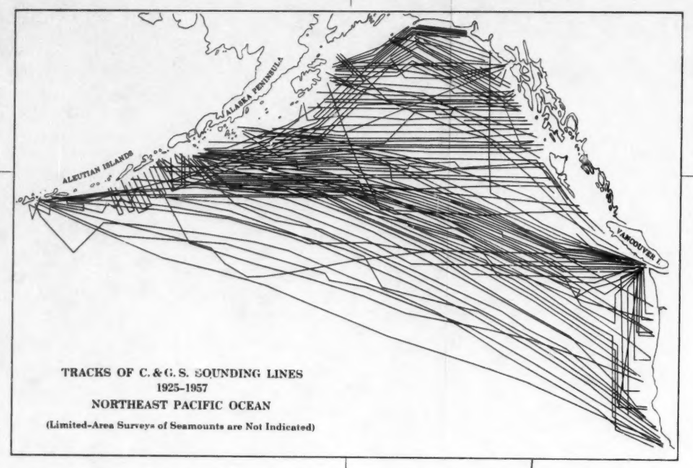
MOGRIDGE L.

KISSING LAKE

MILLS LAKE

LAC CARHEIL

GEOLOGIC MAP AND SECTIONS OF WABUSH LAKE AREA, SOUTHWESTERN LABRADOR AND EASTERN QUEBEC, CANADA



TRACKS OF C. & G. S. SOUNDING LINES
1925–1957
NORTHEAST PACIFIC OCEAN
(Limited-Area Surveys of Seamounts are Not Indicated)

165° 160° 155° 150° 145° 140° 135°
60° 55° 50°

Cook Inlet
KENAI PENINSULA
Prince William Sound
Hinchinbrook I.
Copper River
Cape St. Elias
Kayak I.
Middleton I.
Cape Yakataga
Icy Bay
Yakutat Bay
Dry Bay
Pamplona Ridge
Yakutat Seavalley
Alsek Canyon
Lituya Bay
Cape Spencer
Crest Seamount
Lynn Canal
Icy Strait
Chichagof Island
Baranof Island
Chatham Strait
Peril Strait
Stephens Passage
Frederick Sound
Sumner Strait
Prince of Wales Island
ALEXANDER ARCHIPELAGO
Shelikof Strait
KODIAK ISLAND
Trinity Islands
Semidi Islands
Cherikof Island
Shumagin Islands
Unimak Island
Unimak Pass
Sanak Islands
ALASKA PENINSULA
ALEUTIAN TRENCH
Shuyak Seamount
Dall Seamount
Surveyor Deep-Sea Channel
Kodiak Seamount
Giacomini Seamount
Ely Seamount
Quinn Seamount
Surveyor Seamount
Pratt Seamount
Applequist Seamount
Durgin Seamount
Welker Seamount
Brown Seamount
Baranof Seamount
Dickins Seamount
Denson Seamount
Davidson Seamount
Hodgkins Seamount
Graham Seamount
Bowie Seamount
Miller Seamount
Marchand Seamount
Smook Seamount
Chirikof Seamount
Patton Seamount
Odessy Seamount
Wyer Seamount
Cowie Seamount
Farris Seamount
Hecht Seamount
Murray Seamount
Unimak Seamount
Aleutian Bench
Derrickson Seamount
Wildcat Seamount
Sirius Seamount
Walls Seamount
Shaw Seamount
Gilbert Seamount
Parker Seamount
Guide Ridge
Woodsworth Seamount
Jones Seamount
Bean Ridge
Laskowski Seamount
Whitney Ridge
Pathfinder Seamount
Hook Ridge
Schoppe Ridge
Peters Ridge
J. Morton Seamount
Scott Seamount
T. Morton Seamount
Campbell Seamount
Amchitka Pass
Amchitka Island
Kiska Island
Attu Island
Near Islands
Buldir I.
Agattu I.
Semichi Islands
Alaid I.
Kiska Harbor
Attu Harbor
Agattu Harbor
Buldir Harbor
Semichi Harbor
Alaid Harbor
Kamchatka Peninsula
Commander Islands
Bering Sea
Aleutian Basin
Kamchatka Basin
Kamchatka Trench
Kuril Trench
Kuril Islands
Kuril Basin
Kuril Ridge
Kuril Seamount
Kuril Gap
Kuril Fracture Zone

SUBMARINE TOPOGRAPHY IN THE GULF OF ALASKA

BATHYMETRY FROM DEEP-SEA SOUNDING LINES AND LIMITED-AREA SURVEYS

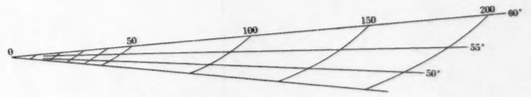
OBTAINED BY SHIPS OF THE COAST AND GEODETIC SURVEY 1925-1957

Depth Contours at 100-Fathom Intervals to Bottom of Rises and Rim of Deeps

Depth Contours at 200-Fathom Intervals on Continental Slope and Seamounts

Dashed Numbered Lines Indicate Profiles on Separate Illustrations

Compiled by W. M. Gibson, Coast and Geodetic Survey



Nautical Miles at Different Latitudes

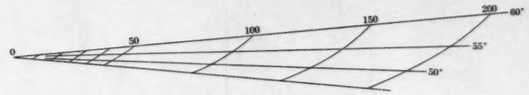
TRACKS OF C. & G. S. SOUNDING LINES
1925–1957
NORTHEAST PACIFIC OCEAN
(Limited-Area Surveys of Seamounts are Not Indicated)

BATHYMETRIC CHART SHOWING SUBMARINE TOPOGRAPHY IN THE GULF OF ALASKA AND LOCATIONS OF ILLUSTRATED PROFILES

Depth Contours at 200-Fathom Intervals on Continental Slope and Seamounts

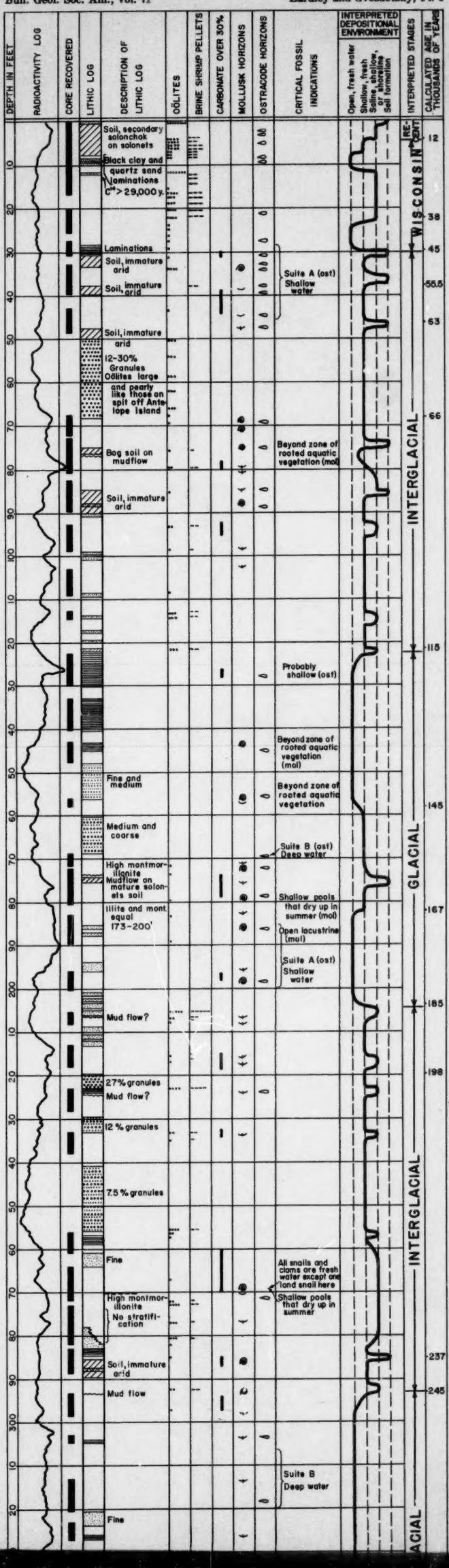
Dashed Numbered Lines Indicate Profiles on Separate Illustrations

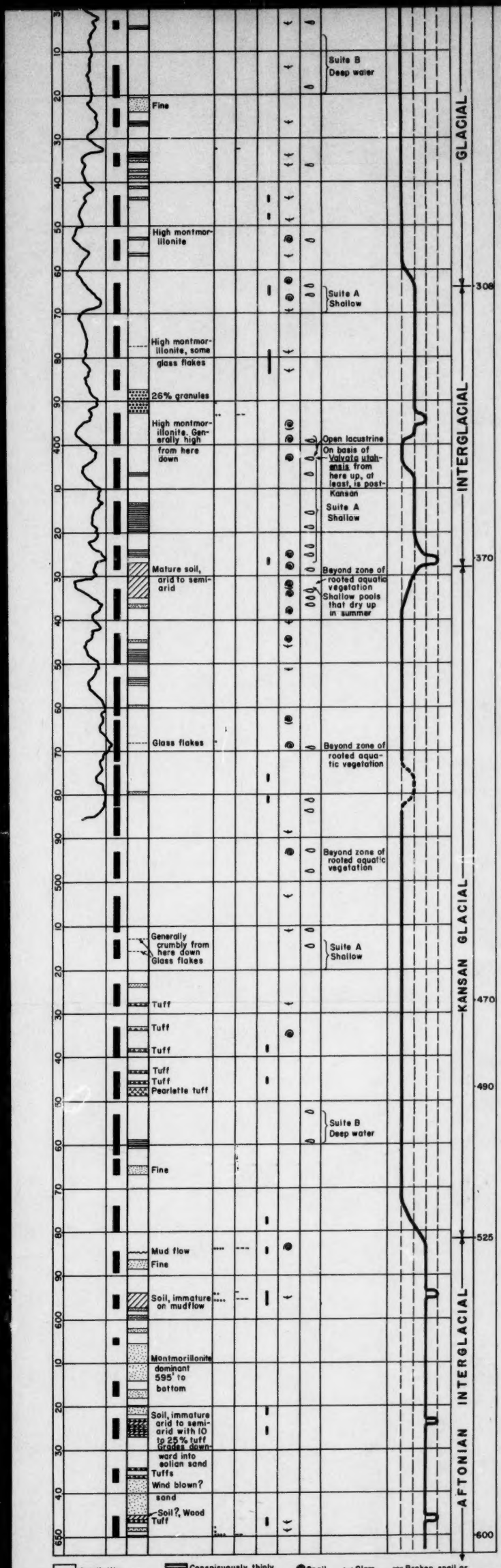
Compiled by W. M. Gibson, Coast and Geodetic Survey



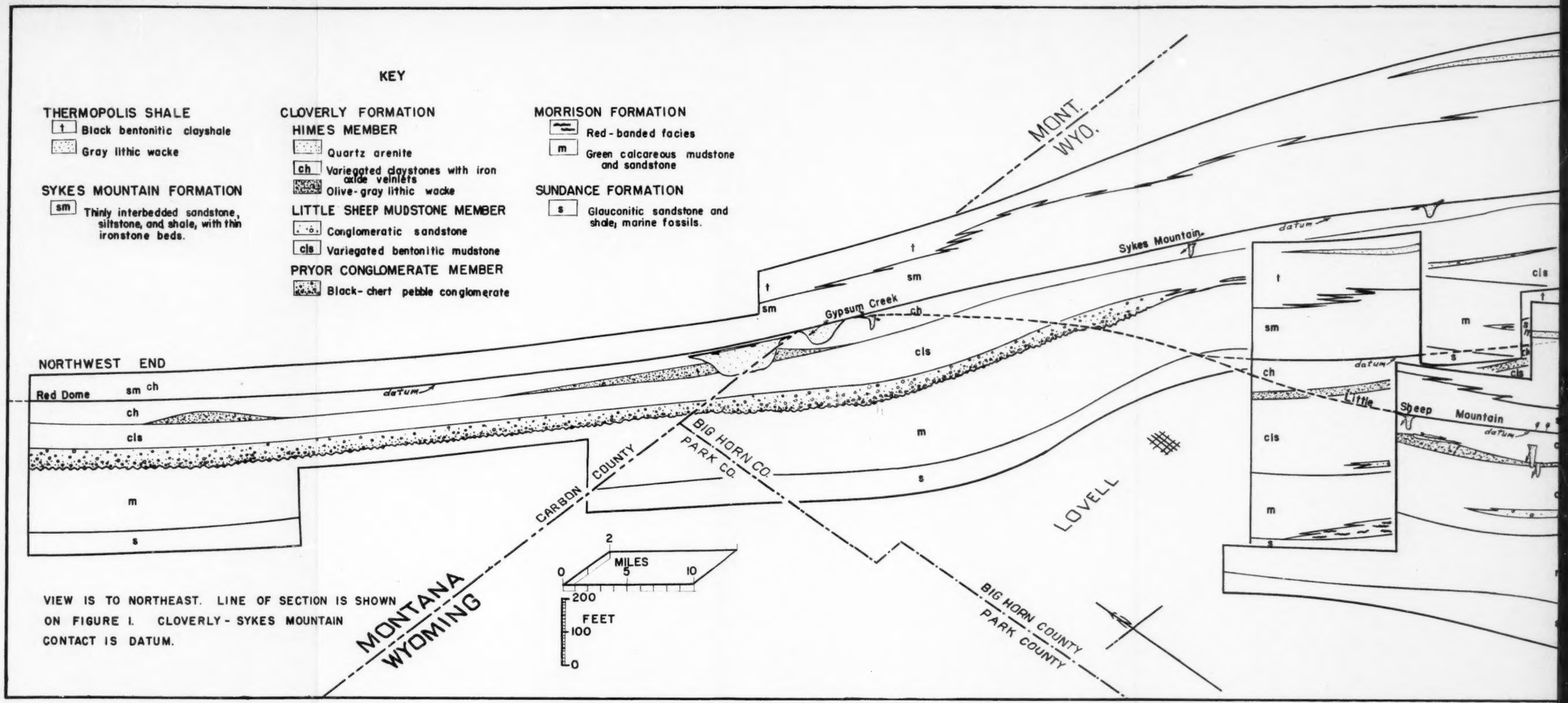
Nautical Miles at Different Latitudes

BATHYMETRIC CHART SHOWING SUBMARINE TOPOGRAPHY IN THE GULF OF ALASKA AND LOCATIONS OF ILLUSTRATED PROFILES


DEPTH IN FEET
RADIOACTIVITY LOG
CORE RECOVERED
LITHIC LOG
DESCRIPTION OF LITHIC LOG
OÖLITES
BRINE SHRIMP PELLETS
CARBONATE OVER 30%
MOLLUSK HORIZONS
OSTRACODE HORIZONS
CRITICAL FOSSIL INDICATIONS
INTERPRETED DEPOSITIONAL ENVIRONMENT
Open, fresh water
Shallow, fresh
Saline, shallow, ephemeral
Soil formation
INTERPRETED STAGES
CALCULATED AGE IN THOUSANDS OF YEARS
Soil, secondary solonchak on solonets
Black clay and quartz sand laminations C14 > 29,000 y.
Laminations
Soil, immature arid
Soil, immature arid
Soil, immature arid
12-30% Granules Oölites large and pearly like those on spit off Antelope Island
Bog soil on mudflow
Soil, immature arid
Fine and medium
Medium and coarse
High montmorillonite Mudflow on mature solonets soil
Illite and mont. equal 173-200'
Mud flow?
27% granules
Mud flow?
12 % granules
7.5 % granules
Fine
High montmorillonite No stratification
Soil, immature arid
Mud flow
Fine
Suite A (ost) Shallow water
Beyond zone of rooted aquatic vegetation (mol)
Probably shallow (ost)
Beyond zone of rooted aquatic vegetation (mol)
Beyond zone of rooted aquatic vegetation
Suite B (ost) Deep water
Shallow pools that dry up in summer (mol)
Open lacustrine (mol)
Suite A (ost) Shallow water
All snails and clams are fresh water except one land snail here
Shallow pools that dry up in summer
Suite B Deep water
RECENT
WISCONSIN
INTERGLACIAL
GLACIAL
INTERGLACIAL
GLACIAL
12
38
45
55.5
63
66
115
145
167
185
198
237
245

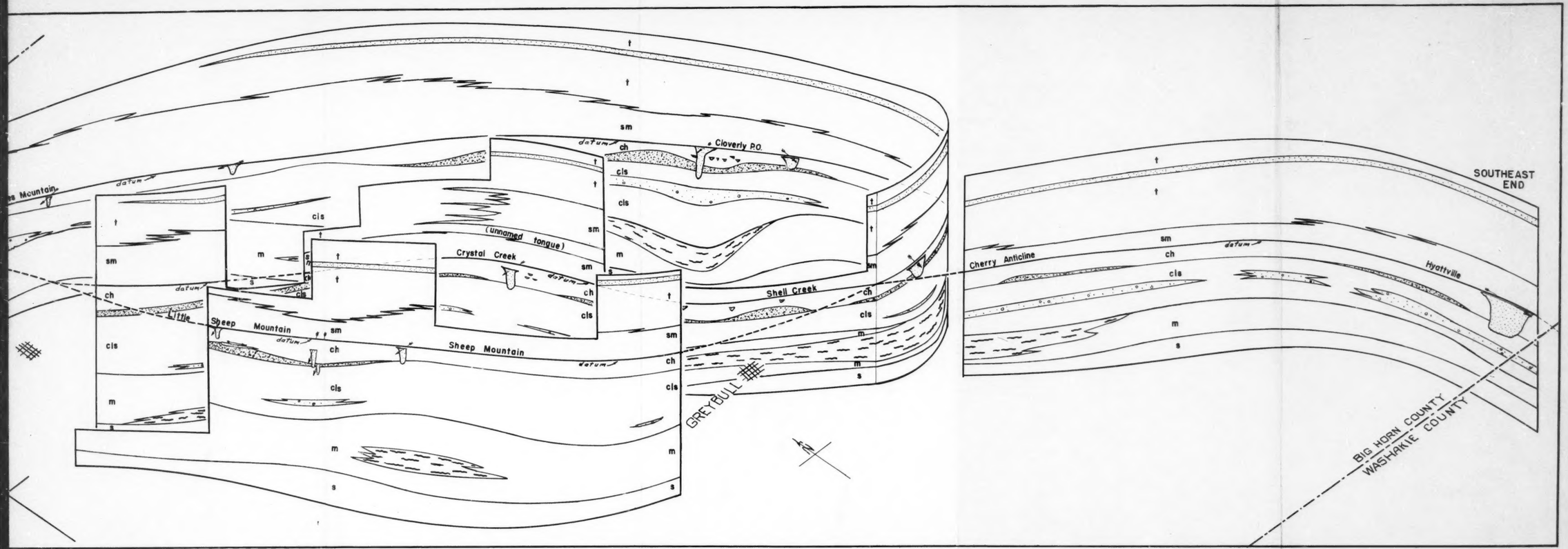


LOG AND INTERPRETATION OF SALTAIR CORE, GREAT SALT LAKE, UTAH



LITHOLOGIC CHANGES IN UPPERMOST JURASSIC AND LOWERMOST CRETACEO

View northeast



OST JURASSIC AND LOWERMOST CRETACEOUS ROCKS ALONG NORTHEAST SIDE OF BIGHORN BASIN, WYOMING AND MONTANA

View northeast into panel diagram

T. 35N.

T. 34 N.

T. 33 N.

T. 32 N.

T. 31 N.

LOCATION MAP

Nevada

50mi.

Contour interval 1000'

Above 6000'

10 mi.

Swails Mtn.

SWAILS

WEST ELKO HILLS

PINON RANGE

PINE VALLEY

Humboldt River

Susie Creek

Middle Fork

Crest

Carlin

Palisade

Pine Mtn

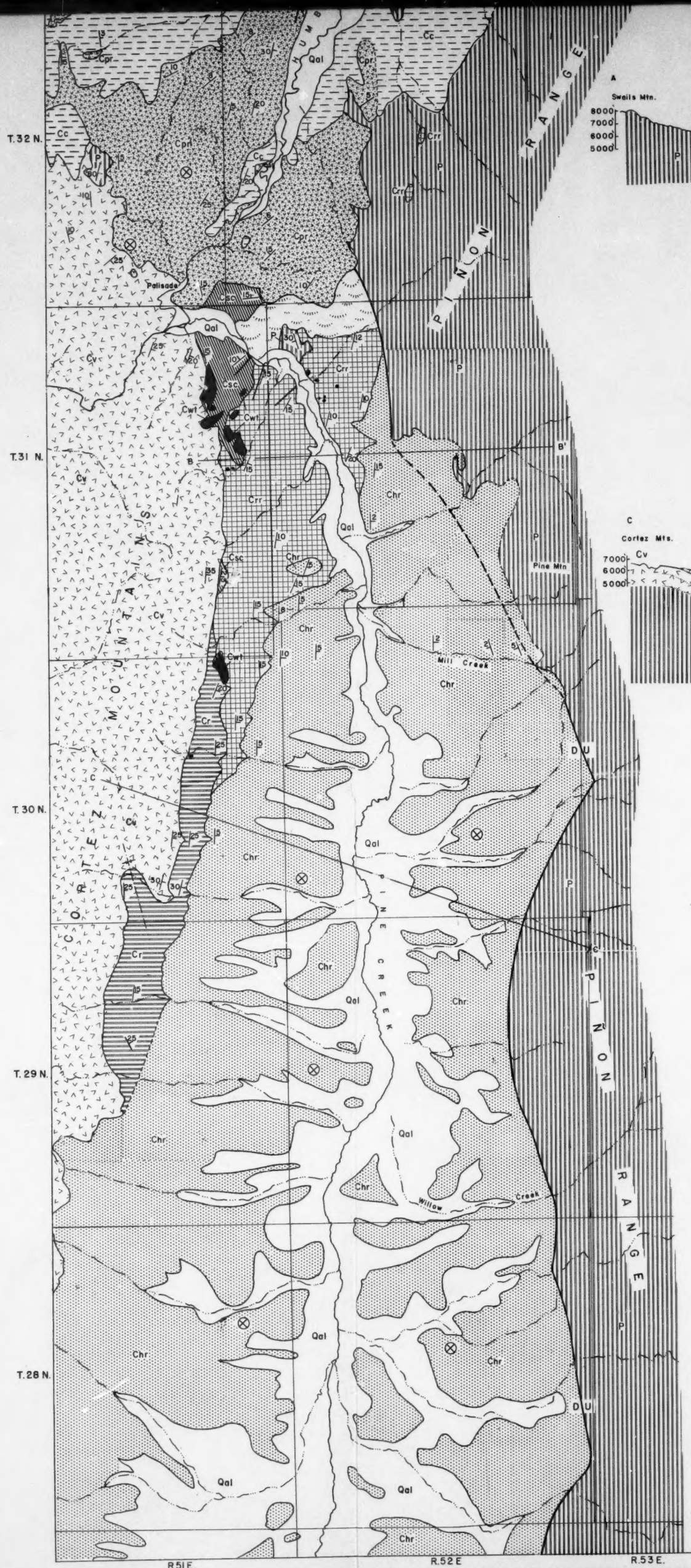
ELKO

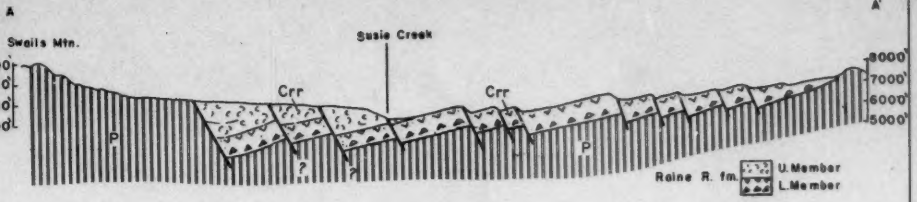
WELLS

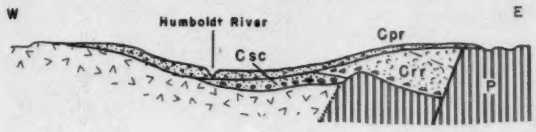
CARLIN

Generalized cross section, north end of Pine Valley

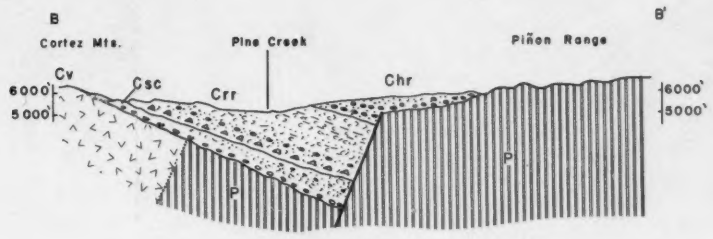
Raine R. fm. U. Member L. Member

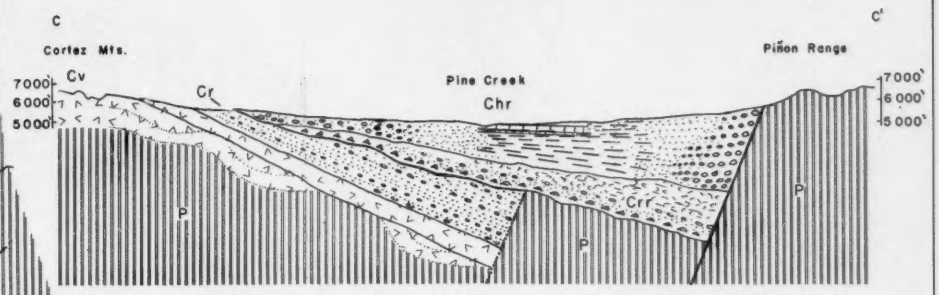






Generalized cross section, north end of Pine Valley





GEOLOGIC COLUMN

Qal	Alluvium (Pediment gravels not represented.)	Late Pleistocene-Recent
Cwt	Welded tuffs	Late Pleistocene
Chr	Hay Ranch formation	Middle Pliocene-Middle Pleistocene
Cc	Carlin formation	Early Pliocene
	Basalt plugs	Early Pliocene(?)
Cpr	Palisade Canyon rhyolite	Late Miocene or early Pliocene
Crr	Raine Ranch formation	Late Miocene
Csc	Safford Canyon formation	Late Oligocene(?) Early Miocene(?)
Cr	Rand Ranch formation	Oligocene (?)
Cv	Volcanics of the Cortez Mountains	Early Tertiary(?)
P	Undifferentiated	Paleozoic

SYMBOLS

- Contact
- Indefinite contact
- Horizontal bed
- A—A' Structure section
- U/D Fault
- Concealed fault
- Inferred fault
- Slump zone

0 1 2 3 4 mi.

GEOLOGIC MAP AND CROSS SECTIONS, VICINITY OF CARLIN, NEVADA

GEOLOGIC SKETCH MAP NAIN-OKAKH SECTION LABRADOR

by E. P. Wheeler 2nd

1957

MILES

0 5 10

LEGEND

1000 Spot heights, Feet above sea level

Adamellite group (P, marginal variants; F, fayalite facies; H, hornblende facies; B, biotite facies)

Minor intrusives (include olivine gabbro, diorite, monzonite, and granodiorite)

Anorthosite group (A, pale; E, buff-weathering; C, dark, often olivine-bearing)

Ultrabasic rocks

Basement complex gneisses (S, younger sediments)

Formation boundary (defined, inferred)

Possible fault

UNGAVA BAY

ATLANTIC OCEAN

NAIN

GOOSE BAY

GULF OF ST. LAWRENCE

60°N

63°

62°

30'

57°

Okhakh Bay

Umiakovik L.

Ella Lake

Norma L.

Khingughutik Brook

Khingughutik L.

Webb Bay

Wilcox Pt.

Tessiuyakh Bay

Nunaingoakh Bay

Kiglitukhpait Mts.

MUTAN (abandoned)

East Okhakh I.

Opungatitkoakh I.

Port Manvers Run

NAIN

GEOLOGIC SKETCH MAP, NAIN-OKAKH SECTION, LABRADOR

EXPLANATION

Diabase dikes

Pegmatite dikes

Biotite-hornblende lamprophyre dike

Serpentine-metagabbro

Wissahickon formation
Garnet-mica schist, biotite-oligoclase gneiss

Cockeysville formation
Quartz metadolomite, phlogopite-calcite metadolomite, calc-schist, calc-silicate marble, diopside-quartz calc-gneiss, calcite marble

Setters formation
Sericite quartzite, biotite-oligoclase gneiss, garnet-mica schist

Baltimore gneiss complex
Migmatite and augen orthogneiss, granodiorite and quartz monzonite

pre-Silurian (Lower Paleozoic ?) — Silurian ? Triassic

GLENARM SERIES

Precambrian

STRUCTURE SYMBOLS

Contacts, exposed, probable, and inferred

Faults, probable and inferred; fault breccia

Foliation

Minor fold axis

Planar calcite fabric in calcite marble

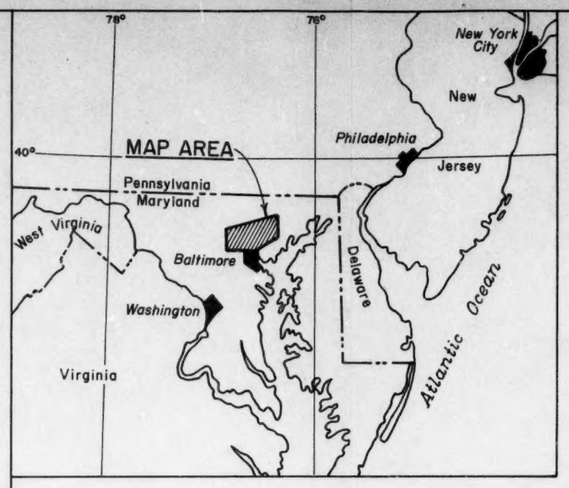
Crinkle fold axis or long axis of boudin

Fracture cleavage

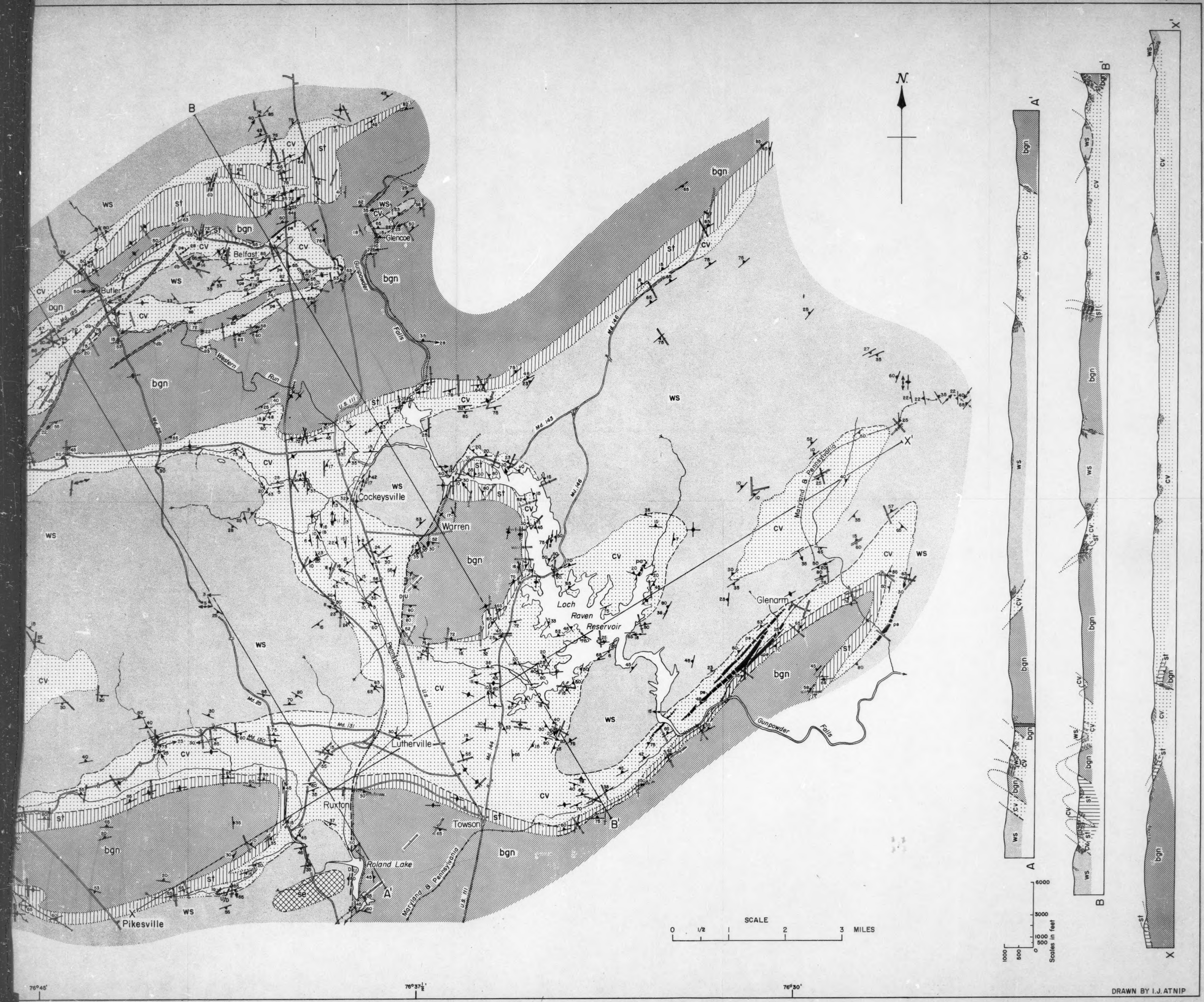
Mineral or aggregate lineation

Joints, dips < 60°, 60°-90°, vertical

Culture abstracted from the Cockeysville, Hampstead, Hereford, Phoenix, Reisterstown, and Towson (Maryland) 7½" quadrangle sheets.



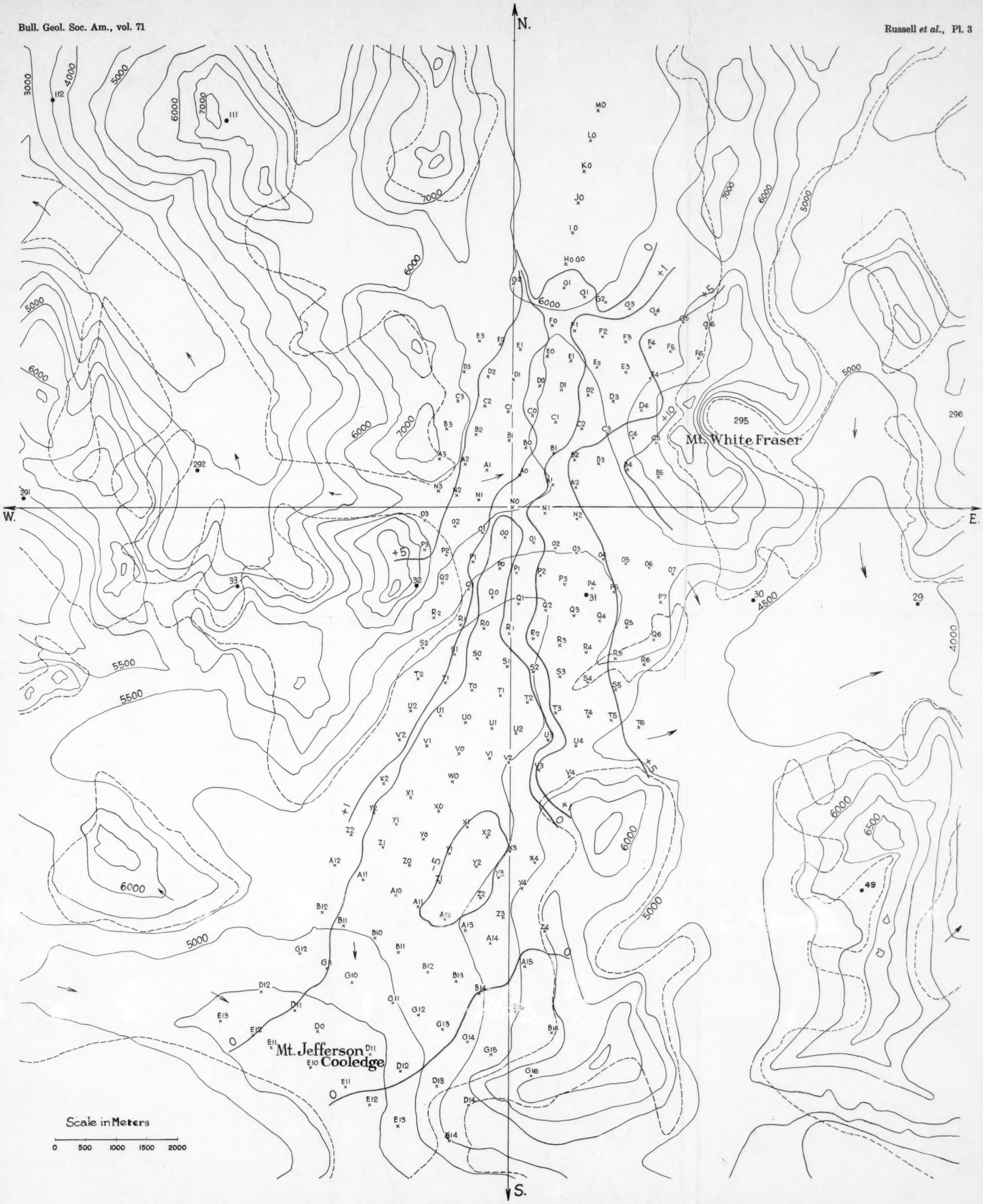
GEOLOGIC MAP OF THE COCKEYSVILLE AREA, MARYLAND



76°45' 76°37½' 76°30'

DRAWN BY I.J. ATNIP

GEOLOGIC MAP OF THE COCKEYSVILLE AREA, MARYLAND



MAP OF SNOW FIELDS, BRITISH COLUMBIA, SHOWING NETWORK OF GRAVITY STATIONS

Bouguer anomalies in milligals

Ranges of important zone fossils
Ammonites
Brachiopods
Fusulines
Propinacoceras Medlicottia
Arlnskia
Parapronorites Eriasgeceras
Cibolites
Xenodiscites Kingoceras
Crimites
Xenodiscus
Adrianites
Eoasianites
Paragastrioceras
Pseudogastrioceras
Strigogoniatites
Jurasonites
Metalegoceras
Neoganides
Agathiceras
Waagenoceras Timorites
Properrinites
Parrinites Popanoceras
Propopanoceras
Cyclolobus
Paritrochia
Stacheceras
Planispina
Uncinuloides
Gyerella
Ctenalosia
Geyerella ?
"Prod." capitanensis
Scacchinella
"Prod." signatus
Derbyia sulcata
Diplanus
Cascinaphora
Fascicosta
? – Derbyia cymbia
Anidanthus
Kozlowskia
Prorichthofenia permiana
Cryptacanthia
Prorichthofenia uddeni
Rhipidomella gaudalupensis
Orthothetina
"Aulosteges"
Paranorella
Juresania ?
Muirwoodia
Stenoscisma hueconianum
Leiorhynchoidea
Stenoscisma venustum
Concrinella phosphatica
"Spiriferina" pakhra
Tegulifera
"Dictyoclostus" huecoensis ?
"Productus" basii
Horridonia
Parenteletes
Glossothyropsis
Limbella wolfcampensis ?
"Aulosteges medlicottianus"
Licharewia
Chonetinella
Orthotetella
"Prod." paradinus
Liosotella scabina
Ombonia
? – Parakayserlingina
Leptodus
Spiriferella scabina
Welleralla texana
Welleralla trassensis
Welleralla swallowiana
Spyridophora
Instifella
Heterelasma
"Productus" semistriatus
Instifella
? – Avonia "boalei"
Neospirifer costellus
? – "Echinoconchus" newsomi
Leella
Schuberiella
S. singi
S. mélonica
Cadonofusiella
Paradoxiella
Triticites
T. powwowensis
T. pinguis
T. victoriaensis
Yabeina
Rauserella
Pseudoschwagerina
P. beedei
P. uddeni
P. stanislavi
Schwagerina
Polydiexodina
S. hawkinsi
S. serum
S. bellula
S. huecoensis
S. gumbeli
S. linearis
S. crassitectoria
S. diversiformis
S. emaciata
Parafusulina
Pt. rothi
Pt. bösei
Pt. splendens
Pt. setteralsi
Pt. wolfcampensis
Pt. kingorum
Pt. diabloensis
Pt. schucherti
Pt. fountaini
Parachwagerina
Paraschwagerina
P. gigantea
Foldvik Creek formation
Nikolai greenstone
volcanics
Unnamed formation in southern foothills
Massive chert limestone
Agglomerate, tuffs and lava flows
Sandstone, limestone, shale, and conglomerate
Lavas and pyro-clastics
Unnamed limestone
Siksikpuk formation
Sadlerochit formation
Tahkandit formation
Unnamed formation
Unnamed formation
Unnamed formation
Cache Creek group
Cache Creek group (present in eastern Wash.)
Granite Falls limestone and unnamed beds
(unnamed beds with Schwagerina)
Clover Creek greenstone
Elk Ridge argillite
Coyote Butte formation
Dekkas andesite
Seven Devils volcanics
Nasoni sh., ls., congl.
Owens Valley formation
McCloud formation
Keeler Canyon formation (upper part)
Anvil Spring formation (upper part)
Seven Devils volcanics
Coast volcanics
Kaibab limestone
"Supai" formation
Bird Spring limestone (upper part)
Weaver rhyolite
Henzel breccia
Rochester trachyte
Limerick kenatophyre
Limestones near Quinn River
Pablo formation
Diablo formation
Wolfcampian Series
Leonardian Series
Guadalupian Series
Word fm.
Capitan ls.
Ochoan Series
No. Word ls.
No. Leonard ls.
Hess ledge
American Standard Section
GREENLAND
Central East Greenland
Amsdrup and Holmsland
ELLESMERE ISLAND
ALASKA
Nushagak Area
North Central Brooks Range
Canning River Area–N.E. Alaska
Yukon Valley–Nation River
Alaska Range
Juneau Region
CANADA WEST
Yukon Province
British Columbia
WASH.
Puget Sound Area
OREGON
Baker Quadrangle
East Central Oregon
IDAHO
Seven Devils Area
Costa Quadrangle
CALIFORNIA
Klamath Mountains
Inyo Range
Panamint Range
Goodsprings Quadrangle
Spring Mountains
Humboldt Range–Quinn River
Round Mt. Quadrangle
L. Triassic
U. Triassic
Triassic (?)
Miss./Dev.
Penn.
M. Baird shale
P. Keeler C. fm.
P. Anvil Spr. fm.
P. Bird Spr. ls.
P. Bird Spr. ls.
Q. Palmetto
Proℂ – L. Carb.
P. Desmoinesian
P. Desmoinesian
Mississippian
M. Alapah ls.
Lisburne group
P(?) Nation R. fm.
P. Sported Ridge ls.
Pablo formation
Weaver rhyolite
Limerick kenatophyre
Limestones near Quinn River
Bird Spring limestone (upper part)
Kaibab limestone
Kaibab limestone
Keiyalo group
Moenkopi
Moenkopi
Moenkopi
Granitville fm.
Weaver rhyolite
volcanics
Nikolai fm.
Nikolai greenstone
Foldvik Creek formation
"Upper Marine" group of Grönwall
Greely Fjord group
Aaiitka group (upper part)
Cache Creek group
Cache Creek group
Granite Falls limestone and unnamed beds
Clover Creek greenstone
Elk Ridge argillite
Coyote Butte formation
Dekkas andesite
Seven Devils volcanics
Nasoni sh., ls., congl.
Owens Valley formation
McCloud formation
Keeler Canyon formation (upper part)
Anvil Spring formation (upper part)
Seven Devils volcanics
Coast volcanics
Kaibab limestone
"Supai" formation
Bird Spring limestone (upper part)
Weaver rhyolite
Henzel breccia
Rochester trachyte
Limerick kenatophyre
Limestones near Quinn River
Pablo formation
Diablo formation
Bird Spring limestone (upper part)
Kaibab limestone
"Supai" formation
Unnamed formation in southern foothills
Nikolai greenstone
Massive chert limestone
Agglomerate, tuffs and lava flows
Sandstone, limestone, shale, and conglomerate
Lavas and pyro-clastics
Unnamed limestone
Siksikpuk formation
Sadlerochit formation
Tahkandit formation
Unnamed formation
Unnamed formation
Unnamed formation
Cache Creek group
Cache Creek group (present in eastern Wash.)
Granite Falls limestone and unnamed beds
(unnamed beds with Schwagerina)
Clover Creek greenstone
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Coyote Butte formation
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Owens Valley formation
McCloud formation
Keeler Canyon formation (upper part)
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Seven Devils volcanics
Coast volcanics
Kaibab limestone
"Supai" formation
Bird Spring limestone (upper part)
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Agglomerate, tuffs and lava flows
Sandstone, limestone, shale, and conglomerate
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Seven Devils volcanics
Coast volcanics
Kaibab limestone
"Supai" formation
Bird Spring limestone (upper part)
Weaver rhyolite
Henzel breccia
Rochester trachyte
Limerick kenatophyre
Limestones near Quinn River
Pablo formation
Diablo formation
1
2
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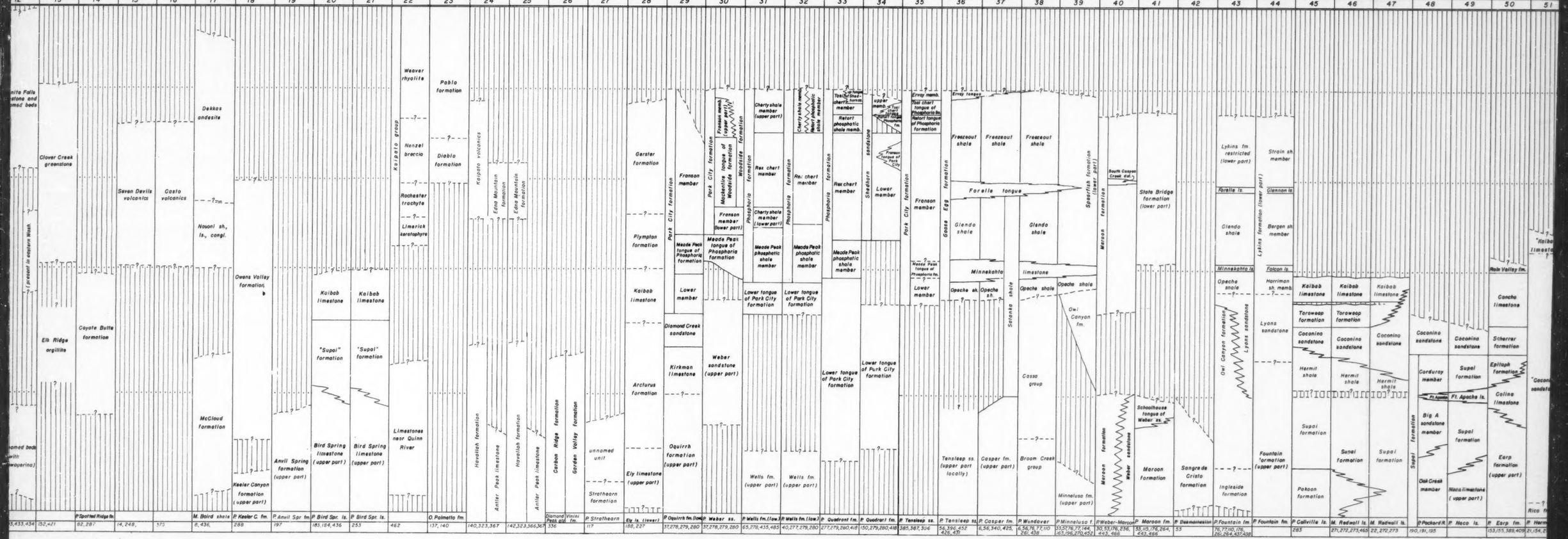
21
22
23
126, 266, 297, 383, 444
146, 164, 444
39, 444
291, 403
349, 420
165, 242, 403
288, 290
58, 286, 308, 309, 310, 311, 368, 376
55, 124, 239
92
7, 16, 92, 254,
14, 103, 433, 454
152, 421
82, 287
14, 248,
375
8, 436,
288
197
183, 184, 436
253
462
137, 140

Chart 7 – CORRELATION OF THE PERMIAN FORMATIONS OF NORTH AMERICA

By Permian Subcommittee, Carl O. Dunbar, *Chairman*

Arthur A. Baker, G. Arthur Cooper, Philip B. King, Edwin D. McKee, Arthur K. Miller, Raymond C. Moore, Norman D. Newell, Alfred S. Romer, E. H. Sellards, John W. Skinner, Horace D. Thomas, Harry E. Wheeler



Prepared under the auspices of the Committee on Stratigraphy of the National Research Council, Carl O. Dunbar, *Chairman*

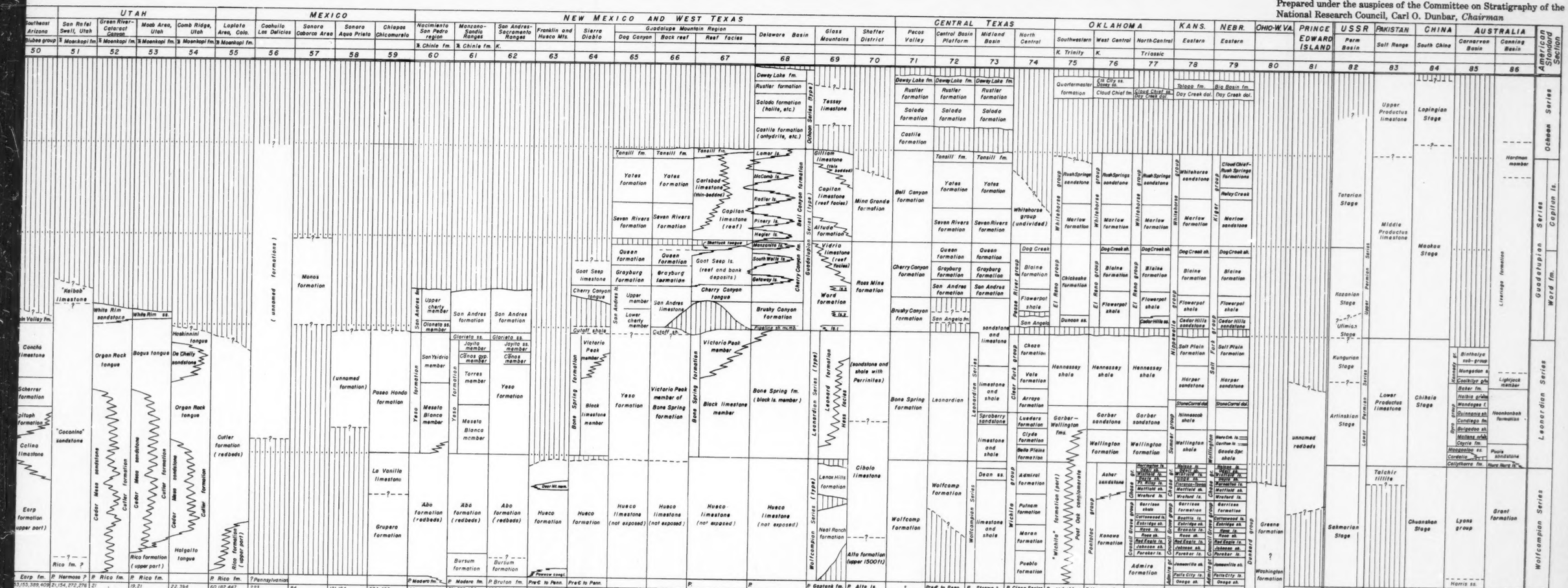

UTAH
MEXICO
NEW MEXICO AND WEST TEXAS
CENTRAL TEXAS
OKLAHOMA
KANS.
NEBR.
OHIO-W.VA.
PRINCE EDWARD ISLAND
USSR
PAKISTAN
CHINA
AUSTRALIA
American Standard Section
Ochoan Series
Guadalupian Series
Leonardian Series
Wolfcampian Series
Permian System
Upper Permian
Lower Permian
Capitan ls.
Word fm.
Delaware Basin
Glass Mountains
Shafter District
Pecos Valley
Central Basin Platform
Midland Basin
North Central
Southwestern
West Central
North-Central
Eastern
Perm Basin
Salt Range
South China
Carnarvon Basin
Canning Basin
Bell Canyon formation
Cherry Canyon formation
Brushy Canyon formation
Bone Spring formation
Victoria Peak member of Bone Spring formation
Black limestone member
Tansill fm.
Yates formation
Seven Rivers formation
Queen formation
Grayburg formation
San Andres formation
Goat Seep ls. (reef and bank deposits)
Cherry Canyon tongue
Victoria Peak member
Black limestone member
Bone Spring fm. (black ls. member)
Lamar ls.
McComb ls.
Kodak ls.
Pinery ls.
Hegler ls.
Manzanita ls.
South Wells ls.
Getaway ls.
Shattuck tongue
Carlsbad limestone (thin-bedded)
Capitan limestone (reef)
Tessey limestone
Gilliam limestone (thin-bedded)
Capitan limestone (reef facies)
Altuda formation
Vidria limestone (reef facies)
Word formation
Lenox Hills formation
Neal Ranch formation
Cibolo limestone
Alta formation (upper 1500ft)
Mine Grande formation
Ross Mine formation
(sandstone and shale with Perrinites)
Leonard formation
Hess Series
Dean ss.
Spraberry sandstone
limestone and shale
sandstone and limestone
Dog Canyon
Back reef
Reef facies
Dog Creek
Blaine formation
Flowerpot shale
San Angelo
Choza formation
Vale formation
Arroyo formation
Clear Fork group
Lueders formation
Clyde formation
Bella Plains formation
Admiral formation
Putnam formation
Moran formation
Pueblo formation
Wichita group
Hennessey shale
Garber–Wellington fms.
Garber sandstone
Wellington formation
Wellington shale
Ninnescah shale
Cedar Hills sandstone
Harper sandstone
Salt Plain formation
Stone Corral dol.
Hutchinson salt member
Nolans ls.
Doyle sh.
Wichita ls.
Clear Fork gr.
Wichita gr.
Archer City group
Quartermaster formation
Clr. City ss.
Cloud Chief fm.
Cloud Chief ss.
Day Creek dol.
Rush Springs group
Rush Springs sandstone
Marlow formation
Whitehorse group
Whitehorse sandstone
Duncan ss.
Chickasha formation
El Reno group
Blaine formation
Flowerpot shale
Cedar Hills ss.
Hennessey group
Hennessey shale
Garber sandstone
Wellington formation
Chase gr.
Council Grove gr.
Admire gr.
Asher sandstone
Council Grove group
Chase group
Admire formation
Konawa formation
Pontotoc group
Wolfcamp formation
Leonardian
Wolfcampian Series
limestone and shale
Dean ss.
Lenox Hills formation
Neal Ranch formation
Cibolo limestone
Alta formation (upper 1500ft)
Bone Spring formation
Leonardian
Wolfcamp formation
Wolfcampian Series
limestone and shale
Dean ss.
Lenox Hills formation
Neal Ranch formation
Cibolo limestone
Alta formation (upper 1500ft)
Tansill fm.
Yates formation
Seven Rivers formation
Queen formation
Grayburg formation
San Andres formation

Chart 10e. – CORRELATION OF CRET

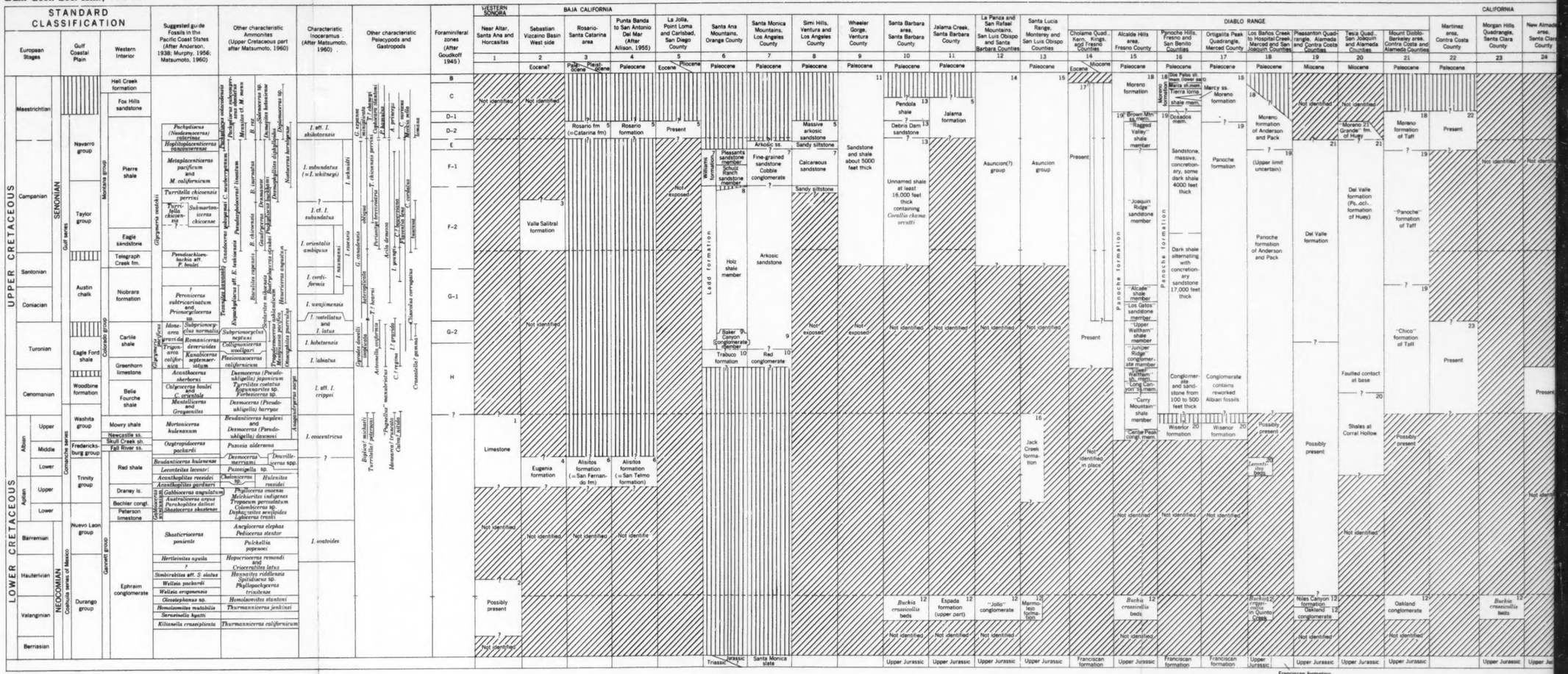
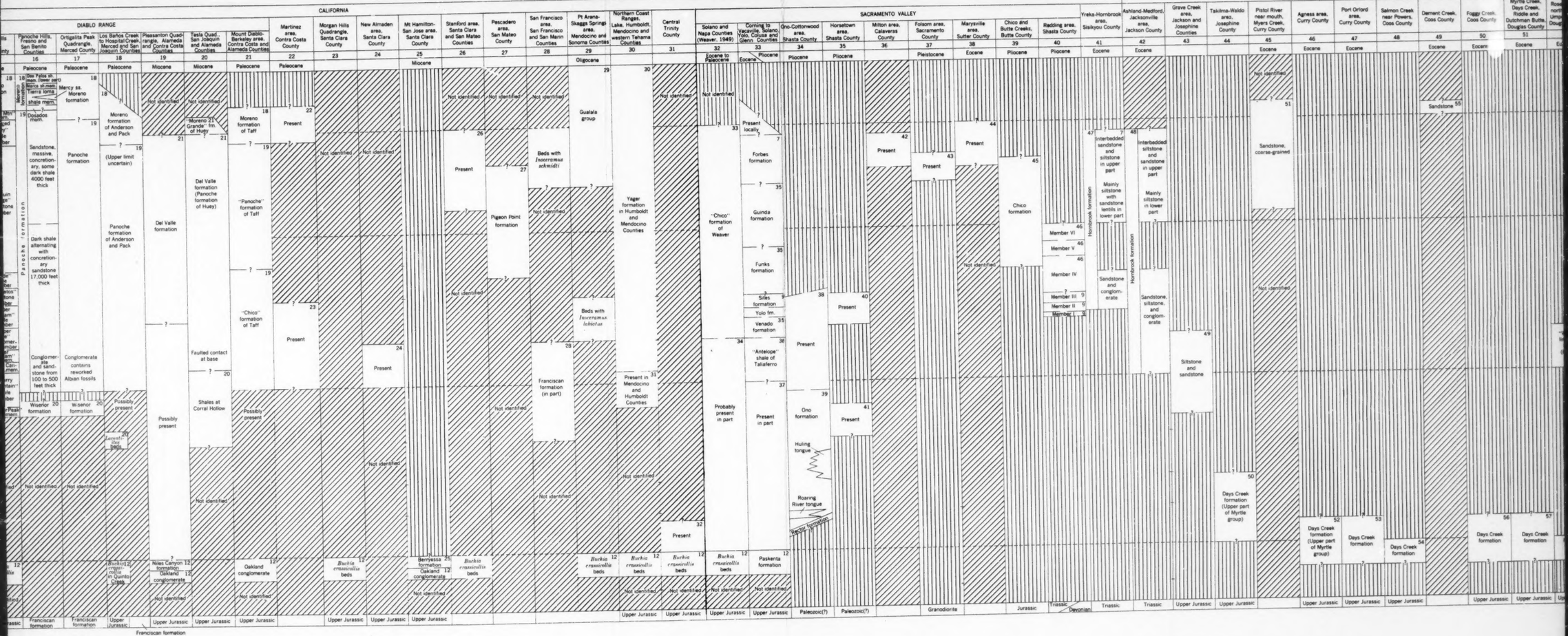
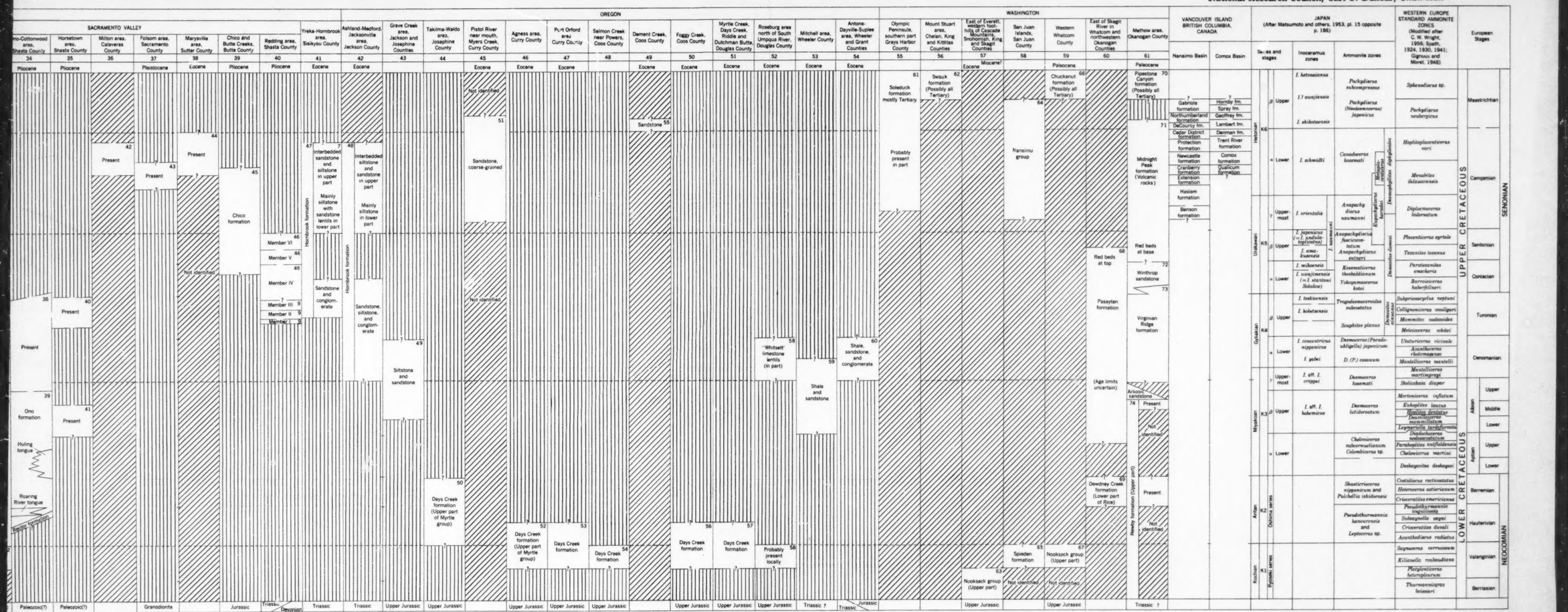


Chart 10e.– CORRELATION OF CRETACEOUS FORMATIONS OF THE PACIFIC COAST (UNITED STATES AND NORTHWESTERN MEXICO)

By W. P. Popenoe, R. W. Imlay, and M. A. Murphy



NITED STATES AND NORTHWESTERN MEXICO)

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